CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

STRATIFICATION FOR THE ARCHAEOLOGIST

Edward Pyddoke

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

STRATIFICATION FOR THE ARCHAEOLOGIST

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

The River Jordan from the air; the river is clearly seen meandering over a level flood-plain with heavily eroded hills on either side.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

STRATIFICATION FOR THE ARCHAEOLOGIST

by

Edward Pyddoke

WITH A FRONTISPIECE,
8 PAGES OF PLATES AND
18 ILLUSTRATIONS IN TEXT

PHOENIX HOUSE LTD

LONDON

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

© *text, Edward Pyddoke,* 1961
Printed in Great Britain in 11 *point Garamond by*
C. Tinling & Co. Ltd., Liverpool, London and Prescot
for
PHOENIX HOUSE LTD
10–13 *Bedford Street, Strand, London, W.C.*2
First published 1961

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

FOREWORD

BY

PROFESSOR S. W. WOOLDRIDGE, C.B.E., D.SC., F.R.S.

AS LONG AGO AS 1688 Dr Robert Hooke foresaw the possible utility of fossils as time-markers: 'However trivial a thing a rotten shell may appear to some . . . yet these monuments of nature are more certain tokens of antiquity than coins or medals and though it must be granted that it is very difficult to read them and to raise a chronology out of them . . . yet it is not impossible.'

Using the clue so indicated William Smith raised Geology to the status of a science.

Now that archaeology has emerged as a scientific discipline from its former role as a mere means of classifying curios, it makes wide demands upon its students for a knowledge of subjects which the Universities still indefensibly group and separate as 'Arts' and 'Science' respectively. Archaeology by its very nature is a bridge subject between these 'Faculties'. The student of human pre-history must necessarily appreciate the methods and conclusions of the historian, but the one point of view with which he cannot dispense is that of the Geologist. But it is not the whole of the modern subject and its diverging specialisms which he need seek to digest. As this book clearly indicates and insists it is Geology as the basic science of the 'field-man' which he needs—a clear appreciation of the principles of deposition and denudation which inform what the author rightly terms an 'eye for country'.

We have already begun to speak of and distinguish between 'dirt-archaeologists' and 'book-archaeologists'. The former, who 'digs', has not only to interpret the stratification of his site but be more widely aware of its environment, both as it is and as it was at the time it was occupied. The South Downs did not wear their present aspect in the days of Neolithic and Bronze Age man, but some features of their form and sub-soil were potent factors in limiting human reactions then as now. To argue thus is not to revive an outmoded form of geographical determinism. Man the inventor, the innovator, has to some degree 'made himself' as Gordon Childe's famous book implies, but we shall not build up a sound archaeology if we ignore the environments, geological, climatic, and botanical, in which he de-

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

veloped. It might thus seem that what the archaeologist requires as his interpretative background is the full range of 'physical geography'. But if he is to gain this wider point of view the road is certainly via geology, or those parts of it which this book simply and clearly emphasizes.

Important though careful and properly localized collection must always be to the subject, the beginner must clearly recognize that his prime task is not to amass curios to adorn a cabinet, but to study the vicissitudes of the human past and the problems they present, as wholes. To do so he must have learned to some measure to think as the geologist thinks and especially to comprehend the basic principles first perceived by James Hutton, but definitively launched upon a slightly incredulous world by Charles Lyell from King's College, London (1830–1833).

I would not have any serious student of archaeology exempted from a perusal of Lyell's *Principles of Geology*, but as a clear, attractive and persuasive introduction to the lines of thought there developed, I could wish them no better beginning than Mr Pyddoke's book.

The archaeologist need not now fear the religious prejudice which Mr Pyddoke's introductory paragraphs briefly recall. Content to learn of creation as a process, the work not of a miraculous conjuror but of an imminent and ever-working God, he can take heart from Proverbs xvii, 24, finding wisdom in the study of processes still acting. The eyes of the archaeological 'fool' have sometimes been in the ends of the earth, but more often in some corner of his own over-prized collection cabinet. Like all the 'field-men' he must 'Come forth into the light of things' and 'let Nature be your teacher'. Then we may append, as others have done, to these words of the great Nature poet, 'Lo! your guide is here'.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CONTENTS

Foreword by
Professor S. W. Wooldridge, C.B.E., D.SC., F.R.S., 5

List of illustrations, 9

Acknowledgments, 11

Introduction, 13

1. The Geological and Geographical Background 19
2. Sun and Air 25
3. Wind 28
4. Rain 34
5. Frost 44
6. Lakes and Ponds 54
7. The Sea 58
8. Rivers and Streams 65
9. Fauna. 74
10. Flora 82
11. Human Settlements 98
12. Interpretation 116

Index 123

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

ILLUSTRATIONS

PLATES

The River Jordan meandering over a level flood-plain . . . *frontispiece*

facing page

I. St Catherine's Monastery, Sinai, set amongst shattered rocks . . . 32

II. Sun-dried mud cracked vertically by contraction 33

III. Iron railings destroyed by acids and electro-chemical action . . . 48

IV. A sandstone cliff showing erosion by wind-borne particles . . . 49

V. The result of erosion by torrential rain, Hong Kong . . *Between pages* 88 *and* 89

VI. An ancient ditch before excavation and showing stages of erosion after excavation . . . . . ,,

VII. A barrow ditch in course of excavation ,,

VIII. Raised beaches at Elie, Fife . . ,,

IN TEXT

FIGURE *page*

1. John Strachey's drawing representing a succession of strata 15

2. Diagram to show how natural 'weathering' by percolating water may result in the production of different layers . 38

3. Gideon Mantell's diagram of the section through strata at Black Rock, Brighton 46

4. Diagrams to show the progressive erosion of a square-cut trench . . . 48

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

5. Diagrammatic representations of the section at Hoxne, Suffolk 50
6. A diagrammatic section through the gravel deposits at Swanscombe, Kent . 68
7. Diagram showing the principal ancient flood-plain remnants in terraces on the south bank of the Thames . . . 69
8. Sketch map to illustrate the meandering course of a river and the formation of river terraces 70
9a. Sketch map of the Farnham, Surrey, area 71
9b. A diagrammatic section of the same area 71
10. Diagrams showing three possible relative positions of two layers of deposits following erosion 72
11. The effects of fast-growing trees . . 85
12. Peacock's Farm: diagrams illustrating the manner in which peat serves to seal in archaeological material . . . 90
13. Plants sealing in broken material . . 96
14. The formation of 'lynchets' or 'cultivation terraces' 100
15. Typical 'frequency curves' to represent the number of pollen grains of different species occurring at different levels . 102
16. The complicated stratification exposed at Jericho 104–5
17. The relationship of stratification to structures (a) retained by cross-section; (b) obliterated by continuous trenching . 119
18. A section cut through layers filling a Roman cellar 120

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

ACKNOWLEDGMENTS

The author and publishers are grateful to the following for providing material for illustrations and for granting permission for its reproduction.

The Royal Society for Fig. 1 (from *Philosophical Transactions* for March, April, and May, 1719); Dr I. W. Cornwall for Figs. 2 and 4 (from *Soils for the Archaeologist*, 1958); R. G. West Esq. for Fig. 5 (from *Philosophical Transactions of the Royal Society*, 1956); The Royal Anthropological Institute for Figs 6 and 7 (from *Journal of the Royal Anthropological Institute*, LXVIII, 1938); Hulton Educational Publications Ltd for Fig. 8 (from *The Physical Geography of River Valleys* by R. Kay Gresswell, 1959); Kenneth P. Oakley Esq. for Fig. 9 (from *A Survey of the Prehistory of the Farnham District*, Surrey Archaeological Collections; drawings based on H. G. Dines and F. H. Edmunds, *The Geology of the Country around Aldershot and Guildford*, 1929); Librairie Armand Colin, Paris, for Fig. 10 (from *La Préhistoire* by Vayson de Pradenne); W. H. Ward Esq. and the Institute of Landscape Architects for Fig. 11 (from *Journal of the Institute of Landscape Architects*, 1947); Professor J. G. D. Clark and the Society of Antiquaries for Fig. 12 (from *Antiquaries Journal*, No. 15, 1935); F. E. Wrighton Esq. and the Corporation of London for Fig. 13 (from *The Natural History of the City of London*, by R. S. R. Fitter and J. E. Lousley); Johs. Iversen for Fig. 15 (from *Landnam i Danmarks Stenalder*, Danmarks Geologiske Undersøgelse, 1941); Dr Kathleen Kenyon and Ernest Benn Ltd for Fig. 16 (from *Digging Up Jericho*); Sir Mortimer Wheeler for Figs 17 and 18 (from *Archaeology from the Earth*, Oxford University Press, 1954).

Paul Popper Ltd for the frontispiece; Beno Rothenberg Esq. for Pls. I, II, and IV; P. C. Lee Esq. for Pl. V; H. J. Case Esq. for Pl. VI, a–d; Nicholas Thomas Esq. for Pl. VII; the Geological Survey and Museum for Pl. VIII, reproduced by permission of the Controller of Her Majesty's Stationery Office.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

INTRODUCTION

THERE ARE BOOKS and reports from which a beginner in archaeology can learn something concerning the identification of antiquities. There are others which deal with the details of strata at some particular site; but there appears to be no publication which will introduce the archaeologist to the great variety of deposits in which antiquities are discovered or to the processes which lead to their becoming buried and preserved.

This book is an attempt to provide such an introduction; my hope is merely that it may stimulate—particularly in those archaeologists who have no formal training in the natural sciences or whose work keeps them much in museums and libraries—an interest in and maybe a fuller study of the many factors and processes which combine in the formation of strata. For, whilst most archaeologists today are aware that the strata or layers to be seen in the sides of almost any trench cut vertically into the superficial coverings of the earth are no longer generally regarded as simply part of the God-given structure of a created world, there do remain those who are content merely to draw and number these strata without always discovering and understanding the method of their depositing.

As far back as the seventeenth century, Sidney Godolphin (1610–43) included in a hymn the words 'Wise men in tracing Nature's laws Ascend unto the highest cause . . .' but, at the time, such an attitude of mind was in fact only partly accepted; indeed, until very late in the nineteenth century belief in slow and unceasing processes of cause and effect was almost heretical. '. . . the temporal power of the Christian church enforced the acceptance of certain dogmatic views about the history of man and nature.'[1]

The accepted view was that the world was created by one act of divine intervention; and even a Vice-President of the Geological Society of London (perhaps because he was also Dean of Westminster) was unable to observe without a background of prejudice. No doubt having in mind the Biblical statement that 'all the high hills and mountains under the whole heavens were covered' by the Flood, he proceeded to the attempted discovery of universal traces of that flood. 'In central Asia', he wrote[2], 'the bones of horses and deer have been found at an elevation of 16,000 feet above the sea, in the Himalay

[1] O. G. S. Crawford, *Archaeology in the Field*, Phoenix House, 1953.
[2] Rev. William Buckland, *Reliquae Diluvianae*, 1824.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

mountains . . . the occurrence of these bones at such an enormous elevation in the regions of eternal snow and consequently in a spot now unfrequented by such animals . . . can, I think, be explained only by supposing them to be of antediluvian origin and that the carcasses of the animals were drifted to their present place, and lodged in sand, by the diluvial waters.'

The facts were being made to fit the theory, but, what is more, so strong was the adherence to the theory that facts and the processes of stratification were not being properly observed. In the same book the author referred to human bones being found eight feet below those of a rhinoceros; '. . . they appear', he wrote, 'to have been introduced at a subsequent period into the diluvian loam, which had before contained the more ancient bones and pebbles; by what means, or at what period of the post-diluvian era, remains yet to be ascertained.' He went on to quote with approval an opinion that the human bones came from a late intrusion, the justification for which belief was that 'all other reported cases of human remains accompanying the bones of beasts of prey have not been confirmed on closer investigation'!

A truly unbiased study of the stratification could have settled the matter and might well have provided us with a very early record of Palaeolithic man.

By 1795 James Hutton had published his *Theory of the Earth* and 'for the first time the geological record was rightly read as a continual change, new continents rising from the destruction of the old by processes of which "we find no vestige of a beginning, no prospect of an end" ',[1] and in 1797 John Frere had considered flint implements from a brickearth at Hoxne in Suffolk to have 'belonged to a very ancient period indeed, even before that of the present world' and yet the Rev. John McEnery, a Roman Catholic priest who excavated at Kent's Cavern, Torquay, seems still in 1830 to have been alarmed at the conclusions he was drawing from his finding of flint blades alongside the remains of extinct animals; he never published his findings.

The dogma of a single act of creation, however, was worrying scientific men and William Smith—nicknamed Strata Smith—who was virtually the founder of stratigraphical studies for geologists, was not afraid to write[2] '. . . Organised Fossils are to the naturalist as coins to the antiquary; they are the antiquities of the earth, and very distinctly show its gradual regular formation.'

Smith's great contribution to geology was to show that fossils included in rocks in one place could help to identify those rocks

[1] See W. G. Fearnsides and O. M. B. Bulman, *Geology in the Service of Man*, Penguin Books, 1944.
[2] William Smith, *Stratigraphical System of Organised Fossils*, 1817.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

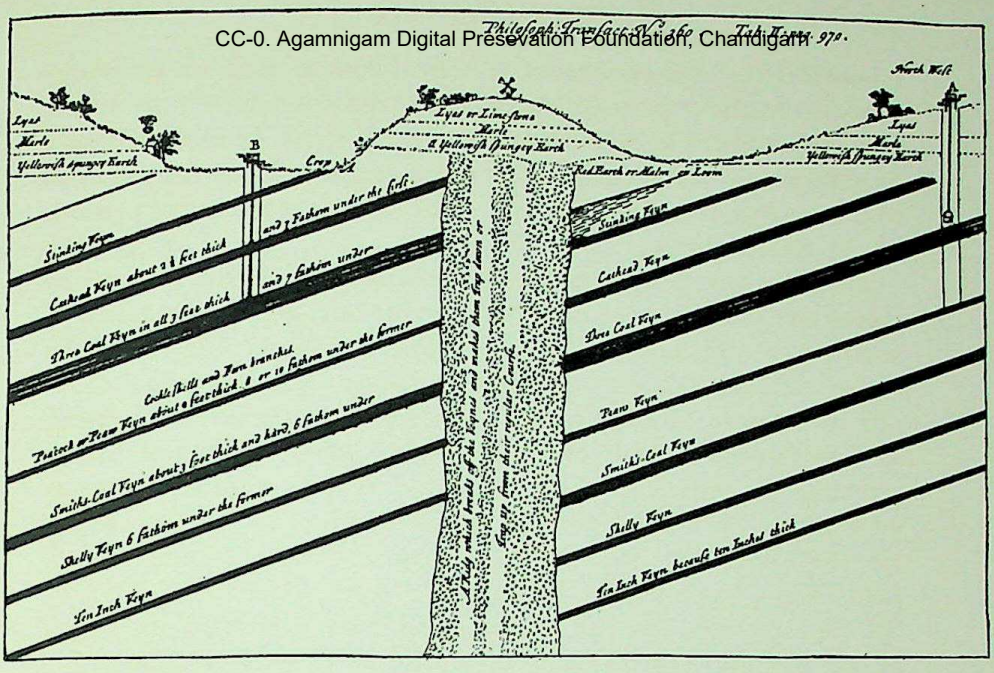


Fig. 1. John Strachey's drawing representing a succession of strata including seams of coal.

at other places, but for archaeologists his most important teaching was that '. . . as the section of a tree shows its increase by annual rings, so the Strata seem to show the earth's lamellar increase . . .'

The mere fact that the Earth's crust was largely composed of layers, however, must have been known in prehistoric times, at any rate by the time that Neolithic miners were quarrying seams of flint nodules in the chalk for the making of their axes. The way in which coal lies in strata must have been known to the Romans and even in Upper Palaeolithic times, for outcrops were used to supply fuel by mammoth-hunters at Ostrave-Petrokovice in Silesia before the maximum of the last Ice Age,[1] but no record of these observations seems to have been made until 1570 when George Owen traced the carboniferous limestone and adjacent coal measures through southern Pembrokeshire and Glamorganshire.[2]

The next noteworthy contribution was one by John Strachey in 1719, in which year he published 'A curious Description of the Strata observ'd in the Coal-Mines of Mendip in Somersetshire . . .'[3]. Figure 1 is a reproduction of Strachey's diagram which clearly shows that he had observed several important points:

[1] Graham Webster, 'A Note on the Use of Coal in Roman Britain', *Antiquaries Journal*, LXXXV, 1955.
[2] See H. B. Woodward, *History of Geology*, Watts, 1911.
[3] *Philosophical Transactions*, No. 360, for March, April, and May, 1719.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

a. that the coal seams had been faulted in a way which 'makes them Trap down or Trap up from their regular course'—though in places discontinuous their relative positions were predictable;

b. that a vertical (volcanic?) intrusion might separate one part of a seam from another;

c. that the beds containing the coal might lie at an angle inclined to the horizontal;

d. that the tilted beds were overlain by more horizontally disposed strata;

e. that these upper beds were discontinuous and had been eroded so as, at least in one place, to expose a surface outcrop of coal.

Strachey clearly stated that there was a succession of rocks, but it was left to Charles Lyell in 1830[1] fully to appreciate 'the continued action of causes still producing similar effects' and completely to reject explanations of phenomena which required the supposition of supernatural events, sudden upheavals, and unique cataclysms. It is important here to note that archaeological strata are nothing more than comparatively recent examples of the effects of geological processes and are manifestations of the same fundamental causes.

A simple exposition of some of these causes and their effects as they concern the archaeologist is the purpose of this book and the word 'Stratification' has been chosen for inclusion in the title so as to lay stress upon the difference between this—the making of strata—and 'Stratigraphy'—the drawing or description of strata.

The forces and phenomena involved in the formation (and disintegration) of strata have been divided, for convenience only, under separate chapter headings but it cannot be stated too emphatically that any number of them may be involved at the same time. Further, many processes are self-contradictory; wind, for example, piles up huge dunes of sand and at the same time tends to destroy them, whilst water, which cuts deep gullies and wadis into hillsides and plateaux, also spreads out level plains of eroded material. Since all the forces may work together or against each other at the same time any divisions in the book must be entirely arbitrary. It will be found therefore that repetitions have sometimes been unavoidable and that it has not been possible to include every reference to any particular force in one section. Archaeology cannot properly be dissociated from ecological and environmental history, from geology, geography, climatology, and similar studies, works on which the librarian tends to put on different shelves; he catalogues and treats them as different 'subjects'

[1] Charles Lyell, *Principles of Geology*, 1830–3.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

but, as Herbert Spencer wrote: 'Not only are the sciences involved with each other, but they are all inextricably interwoven with the complex web of the arts, and are only conventionally independent of it.'

The vertical side of any excavator's trench displays a section through superimposed strata and almost every archaeologist today will record the thickness and extent of these layers and carefully note the exact position in them of his 'finds', but an excavation report is not complete unless the writer sets out to explain the manner in which the layers were deposited. To understand his site properly the stratigrapher must always ask himself how his finds reached the position in which he discovered them; his little sequence of strata can no longer be regarded just as a heaven-sent means of separating cultural levels, nor can deposits be regarded as meaningless and 'barren' simply because no recognizable artefacts or organic remains are discovered in them. They are all equally important parts of a continuing record. Just as in the case of a cine film, it should be possible to re-tell at least some story even if parts of the recording have been blurred, displaced, or cut away.

The interpretation of stratigraphy I have mentioned only very briefly albeit this is one of an archaeologist's most important tasks. My reason has been that interpretation is something which must be learned in the field; no attempt to provide a handbook could be successful nor, if it were to be written, could such a publication take the place of practical experience. A wealth of special knowledge gives the archaeologist no exemption from a requirement to observe nature at her everyday work, and stratigraphy will not provide the fullest information unless the strata are observed by someone who has an 'eye for country' and who can mentally restore both the environment at the time of their deposition and the processes of aggradation, erosion, and disturbance which have in the past affected and may still be affecting them.

Finally, there is no need to search far afield for examples of stratification; most, if not always all, of the processes, natural and human, which lead to the formation and destruction of strata can be seen and studied actively operating almost everywhere. 'Wisdom', says the proverb, 'is before him that hath understanding; but the eyes of the fool are in the ends of the earth.'[1]

[1] Proverbs xvii, 24.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

1

The Geological and Geographical Background

COMPARED WITH THAT of other forms of animal life the development of Man is something very recent. The very earliest traces of him or his implements are less than one million years old and are found only in deposits which the geologist, who is concerned with the whole history of the Earth's rocks (the oldest of which is now regarded as being some three thousand million years old), regards as superficial and ephemeral.

The concern of the archaeologist must obviously be primarily with these superficial deposits, whether they include the gravel beds of extinct rivers, the dusts and sands which are daily transported by the wind, or the heavier material moved by volcanic and glacial forces. None the less he should have some understanding of the buried rocks of the area in which he is working, for not only are they generally parent to the surface layers but they exercise a major control over the living world above them.

The archaeologist should therefore equip himself not only with topographical maps but also with maps which show respectively the 'drift' (superficial) geology and 'solid' (underlying) geology of his area—and he should arm himself also with the ability to interpret the geologist's conventional representations, for a little application will result in the understanding of a geological map not only as a two-dimensional plan but also as a diagram showing in which direction and at what angle layers of rock are tilted.

Whatever may have been the original position of the solid rocks, almost universally they have subsequently been warped and contorted to a greater or lesser extent. In places this folding has brought very ancient and once deeply buried rocks to the surface and everywhere has resulted in cracks and weaknesses. These 'tectonic' movements have largely dictated the shape which the surface of the Earth has subsequently (and sometimes concomitantly) assumed, for so have the hills and mountains been raised and some of the valleys been formed.

This up- and down-warping has ordered the direction in which surface-water shall drain, which shall be areas subjected to denudation and which to protection by new layers of accumulating debris. It has

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

ordered also the flow of water below ground, for surface-water will percolate downwards through less compact layers and be ponded and forced to move sideways when it reaches an impervious stratum. Eventually this water may re-appear as springs of fresh water, but the points where such springs appear will depend upon the nature and inclination of the deep-seated 'solid' rocks.

Such springs have encouraged vegetation and attracted man and beast at all times. One thinks of Elisha's Well, which was the *raison d'être* for the oasis and early settlement at Jericho, and of the line of springs at the foot of the North Downs in Kent and Surrey, where the pervious hills of the Chalk escarpment lie upon the impervious Gault Clay. By many of the springs is a village, descendant of a Jutish settlement, whilst never far from water, on dry ground just above the spring-line, runs the pre-Roman Iron Age (or earlier) 'Pilgrims' Way'.

Dependent on the nature and porosity of the rocks—which, for geologists, include clays and sands—is the amount of water which can be held by them. Many open-textured sandstones and limestones will hold water as does a sponge, whilst some of the compact volcanic rocks will retain hardly any.

In pervious and soluble beds streams may excavate for themselves a subterranean course and may only appear on the surface as 'winter-bournes' or 'nailbournes' in time of spate—a fact known to the Saxons, who not infrequently sank wells into the bottoms of dry valleys, so as to tap the underground watercourse. Upon the nature and structure of the rocks will also partly depend the height of the permanent water-table—though this is also affected by climate and covering vegetation. The bottoms of two Romano-British wells in the village of Woodcuts, excavated by Pitt-Rivers, are considerably above the level of the water-table of today.

Sir Cyril Fox[1] has drawn attention to the different ways of life forced upon men of all periods who lived in the 'Highland' and 'Lowland' zones of Britain, zones which depend for their existence upon the underlying rock systems; he is however but one of many writers who have shown how geology affects vegetation and so also the animal kingdom.

The rocky structure of the landscape has always in the past controlled, and still continues to control, human transport and communications. Standing apart from those tracks which, like the Pilgrims' Way, follow the spring lines, are the ridgeways, which follow the even crests of uplands so as to avoid the marshes and forests below. The route of the westward-moving Celts through the Belfort Gap was

[1] *The Personality of Britain*, National Museum of Wales, 1932.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

forced upon them by considerations of geology and the existence to either side of trackless rocky barriers, and it is not without interest to compare existing road and railway systems with the lines of communication of two thousand years ago; many of the rivers and hills which were barriers then are still barriers today.

However, a relief map of the modern countryside is not always sufficient for the archaeologist who wishes to work out prehistoric trade and migration routes, for, even if he is in possession of information concerning local changes in climate, without a knowledge of the geology of his area he will be unable to form a mental reconstruction of the natural barriers of marsh and forest which once barred or complicated passages that may now be easy. Drainage, for instance, may have encouraged the growth of passable oak-forest where the natural growth would have been impenetrable alder-swamp.

A study of geological maps will often explain and sometimes lead to the discovery of the course of early roads, when maps of modern topography have failed. As an example, a strange 'kink' in the line of Roman Stane Street near Ewell, Surrey,[1] was found to result from the makers' wish to leave the water-retaining London Clay and to reach the firm dry Chalk as soon as possible. The modern drained and deforested landscape fails to disclose what to the Romans must have presented an important problem.

An archaeologist, whatever the period which may concern him, should be able to recognize immediately fragments of rock from local strata if only in order that he may be able to note others which are not 'native' to the district. From such 'erratics' the man whose work concerns the Palaeolithic may be able to identify the source of the rock debris left by former ice-sheets, whilst the worker on later periods may be able to recognize stones transported by human agency. The course of a Roman road in Kent was traced as a result of stones foreign to the district being noted amongst the roots of some bushes, whilst in Sussex a mediaeval village was discovered as a result of the finding of fragments of a German Niedermendig lava which had been used for corn-grinding stones. The recognition of the 'Blue Stones' at Stonehenge as being of Welsh origin is well known.

Equally important to the archaeologist are the natural form and fracturing of local rocks. Much time would have been saved at Oldbury, Kent, had the excavators known at once that what was carefully cleared as a possible artificial flooring of stone slabs was in fact a widespread (and locally well known) natural layer of secondarily silicified material in undisturbed sand.

A knowledge of bedding and cleavage planes in local rocks will

[1] I. D. Margary, *Roman Ways in the Weald*, Phoenix House, 1948, p. 74.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

similarly at once make clear which stones are naturally fractured and which may be considered as artefacts.

Part of the self-questionnaire issued for the use of his assistants in the field by Sir Mortimer Wheeler, when he was Director-General of Archaeology in India, may be quoted:[1]

'1. Have I with me the best available map of this region, and am I constantly referring to it?

'2. Do I know the main elements of the basic and superficial geology of this region? Have I studied the appropriate sections of the Gazetteer?

'3. Do I know something of the climate, irrigation and agriculture of this region?

'8. What are the geographical, geological and other reasons for the part played by this region in the general development of human culture? Has it special economic resources of its own . . . etc.?'

It is the provision of answers to such questions as No. 8 that leads to the writing of history and prehistory; for the site of man's activities must be explained as well as being merely surveyed, excavated, and reported.

The course of roads and the position of settlements is affected by but not entirely controlled by geology, and it is the task of the archaeologist to answer the question 'Why was the antiquity with which I am concerned found in the position in which it was?' Later chapters will deal with the manner in which strata may have been formed or destroyed since the time of the antiquity's manufacture by man, but the question will arise, how was the site formed by nature and why was it chosen by man?

An examination of present-day or past topography alone may not always supply the answer; no explanation may be forthcoming as to why the occupant of a remote Bronze Age burial cist was living in such inhospitable country until a geological survey perhaps shows that workable copper ores are or were to be found in the neighbourhood.

It has been said that man chooses and then utilizes the site prepared by nature and it is obvious that in his selection man will have to decide what are his requirements; to achieve some amenities he may have to forgo others. If he wishes to construct a fort he may have to make a choice between an impregnable but waterless hill and a less easily defended but well-watered site. He will have to decide whether or not his enemies are likely to lay siege to his stronghold, and having done so he must then make a selection from what nature has provided; the

[1] Archaeological Survey of India, Staff Memorandum No. 5.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

subsequent history of the chosen site will show the effects of human and natural activities alternately or contemporaneously.

In having this ability to foresee future needs man differs from the rest of the animal kingdom, which reacts principally to immediate stimuli; and in making provision for his future requirements—by quarrying, ploughing, tree-felling, draining, dredging—he has become one of the principal agents in shaping, literally, the face of the Earth. Man is also a great traveller and transporter of materials, his powers in this respect far exceeding those of any other animal.

All living matter, both animal and vegetable, has the ability to grow upwards and so, in part and temporarily, to overcome the ubiquitous force of gravity; further, most living matter attempts to select or remain in a certain place and moves or takes root so as to do battle with the elements. In both respects most living matter thus differs materially from inanimate matter, which takes up, without resistance, whatever position the combined natural forces dictate. Over a large part of the surface of the globe, however, animate and inanimate are closely linked and are factors of equal importance in the development of landscape.

The Introduction to this book has stressed that the factors and forces controlling the constant shaping and reshaping of the Earth's surface continue to be very much the same as those which shaped it in the past; it has also been said above that the archaeologist is mainly concerned with superficial deposits. Let us briefly consider the nature of what Sir Mortimer Wheeler's questionnaire refers to as 'basic' geology.

Below the surface accumulations of geological debris (which may vary in depth from millimetres to many hundreds of metres) are successive layers of rocks, almost all of which have begun their history, because of the effects of gravity, as horizontal spreads—whether the composing materials have been provided by volcanic flows or by a rain of microscopic animal skeletons onto the floor of a deep ocean. The weight of superimposed layers has usually compacted and hardened these materials until they have become firm and solid. (Subterranean heat and chemical and other actions may assist in altering their constitution.)

Whenever the rocks have been elevated by earth movements or otherwise exposed and there has no longer been any material being deposited on and protecting their surfaces, they have immediately become subject to erosive attack by the 'elements'; as they have been attacked they have begun to break up and the fragments have eventually become incorporated in a new deposit. The nature of this breaking up and redeposition is the basis for the following chapters.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

Sometimes succeeding layers lie parallel to each other, one above the other; elsewhere earth movements have taken place between periods of deposition, so that the first layers have no longer been lying horizontal when the next layer was laid down—but these basal rocks nearly all have this in common, they extend over wide areas and individually change only slowly in composition from bottom to top and from place to place. What was in their time the superficial and local debris has normally been completely eroded before the deposition of the next layer of thick rock; exactly similar erosion and extensive deposition is continuing now. Owing to the brevity of man's history on Earth it is only in the ephemeral and local deposits of the Earth's present surface that we can hope to find his remains and artefacts.

In a book of this nature no more than passing reference can be made to some factors in the formation of the Earth's habitable surface, among them major earth movements, albeit they may have the profoundest effects. A brief mention of earthquakes and vulcanism however cannot be omitted.

Comparatively recent subsidences of the floor of the African Rift Valley have resulted in some parts of strata containing Upper Palaeolithic implements sinking to a lower level than other parts of the same strata whilst, in the same area, contemporary volcanoes produced important spreads of lava and volcanic ash.

The layers of volcanic material from Vesuvius which buried Pompeii and Herculaneum are well known, and elsewhere a slow sinking of the land-surface has resulted in depressions into which silts have been washed and where they have accumulated.

It may be as well to conclude this chapter with some words written in the early part of the seventeenth century: 'Geography without History seemeth a carkasse without motion, so History without Geography wandreth as a Vagrant without certaine habitation.'[1]

[1] John Smith, *General Historie of Virginia*, 1624.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

2

Sun and Air

THE CONTINUED FORMING and reforming of the rocks has resulted in every rock's being composed of an aggregation and mixture of minerals and particles. The sedimentary rocks are usually held together by a variety of cementing materials and are generally softer than rocks of igneous origin, which retain their form through the cohesion of crystals which formed during the process of their cooling: however, the harder rocks are not necessarily more resistant to all forms of 'denudation'—a general term covering the effects of all erosive forces.

Because of this lack of homogeneity the rocks all have in themselves the seeds of their own destruction, for each crystal and mineral has its own coefficient of expansion. Since the whole of the surface of the Earth is subject to changes of temperature of greater or lesser degree exposed crystals and minerals are subject to expansion and contraction, and such changes are differential between the composing substances. Great stresses are set up and when these become insupportable the rock surface breaks.

In tropical countries, especially where, as in dry regions, the sky is clear and radiation uninterrupted, differences between daytime and night temperatures may be very great and be reached very rapidly. Such changes can result in the disintegration of rock surfaces on a very large scale (Plate I) and are the cause of the piles of angular 'scree' at the foot of rocky slopes in desert regions.

Even in high latitudes the Sun can sometimes produce very high temperatures in exposed rocks and, especially if cooling is rapid, as is the case when there is a sudden thunderstorm, splintering and exfoliation from the parent mass may result.

On level ground the detached fragments remain above the solid rock beneath and serve temporarily as a protective blanket. But on sloping ground rain, wind, frost, gravity, and to a lesser extent animals and vegetation combine to remove them downhill and to re-expose the rock below.

The process continues: the Sun's heat works on the fragments themselves, expanding, splintering, and re-splitting them until they become —in arid areas—desert sand and eventually dust. To this reduction in

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

size there finally comes a limit; according to Professor Zeuner,[1] when the grains reach a diameter of between one-tenth and one-hundredth of a millimetre. When, indeed before, this stage is reached the rock powder is easily disturbed and transported by movements of the air.

The heat of the Sun, of course, is responsible for the melting of fallen snow and when thawing is rapid torrents of melt-water can be extremely violent and destructive.

It may be unnecessary to add that changes in the amount of solar radiation reaching the Earth's surface are, in fact, eventually responsible for almost all erosion and deposition since they are the cause of wind, rain, frost, and all the wide ranges of climate.

Heating of an originally wet deposit will normally result in its desiccation and shrinkage. In the case of dried mud the reader will have noticed a division and cracking of the surface into polygons (Plate II). When, as is the case with lake-bottom sediments, the mud has been deposited in strata, the top layer will curl away from those below and will then be liable to removal by wind. This mud of lake sediments, as will be explained in Chapter 6, is composed of alternating layers of fine and coarser material. The topmost, which is composed of the finest clay, shrinks most on drying and so separates from the sandier and less coherent layer below. The vertical cracks in sun-baked mud may be very deep and often of considerable width: it is as well therefore for the archaeologist to bear in mind the possibility of human artefacts falling down such cracks to levels well below those upon which they were first deposited.

In dry sun-baked areas evaporation at the surface may result seasonally in a capillary rise of ground-water. Instead of being washed downwards and away from the surface soluble minerals and salts are carried upwards and then deposited on or near the ground's surface. This results in a concentration of salt and alkali in the ground and helps to ensure its barren nature. The archaeologist is interested for the reason that his finds in such circumstances are strongly impregnated: when objects are removed from the earth these salts are liable to re-crystalize and so destroy the substance containing them by pressure from within. Only thorough soaking of the finds in an acid solution will remove the salts and render the objects safe.

The air itself, quite apart from those erosive effects which are described later under the heading of 'Wind', assists in the disintegration of the Earth's crust.

Under the influence of changes in temperature and barometric pressure the air absorbs or rejects moisture in the presence of which two of its important components—oxygen and carbon-dioxide—are

[1] F. E. Zeuner, *The Pleistocene Period*, Ray Society, 1945.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

able to effect the chemical disintegration of rock. Oxidation is of considerable importance as a weathering agent. The rusting of unprotected ironwork is well known: perhaps less familiar is the fact that the red or yellow colour of nearly all surface deposits is the result of the inclusion in them of iron compounds which have been attacked by atmospheric oxygen.

Nitrogen from the air is fixed by soil bacteria and so made available to plants for inclusion in their tissues, and simultaneously oxygen, hydrogen, and other elements are undergoing changes as the result of bacterial life, much of which is air-borne.

In cities the concentration of sulphurous fumes is sufficient, with moisture, to form appreciable quantities of sulphuric acid: stone and metal-work are both attacked and soil formation is assisted. The effects are most obvious in places from which water drips or where it evaporates. An electrolyte is also provided which assists in the electrochemical destruction of metals: iron railings seated in lead will rapidly decay in a damp city atmosphere (Plate III). Perhaps it is not inappropriate to say that it is electrical movements generated between different metals which result in the corrosion of many copper coins and the safe survival in their midst of similar coins minted in silver—and similarly the survival of gold at the expense of adjacent silver.

Lastly, the air itself chemically assists erosion. Not only does the comprising oxygen assist in the formation of rusts and oxides but it may so affect some substances as to render them more subject to attack by other elements. Iron sulphide, for instance, is rendered soluble by aeration; by taking up oxygen insoluble sulphides become soluble sulphates.

These disintegrations all provide material, in greater or lesser amount, for new strata to be deposited on the Earth's surface and begin the story of stratification.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

3

Wind

LET US NOW consider the effects of wind. Every local change in the temperature of the atmosphere causes currents in the air, from imperceptible movements to hurricanes and tornadoes. Whilst wind can so lash the sea as to build up waves of enormous destructive power (see page 58), on dry land sheer wind pressure can blow down a wall, lift a roof, uproot trees, or roll solid objects along for short distances, but the wind's main erosive effects are achieved by its lifting loose particles and transporting them for distances which depend upon their size and its own energy.

Gusts and eddies in the air will thus pick up the lightest particles first and carry them away—in whatever direction the wind may be blowing—leaving heavier material behind either subsequently to be blown away by stronger winds or to remain awaiting erosion by other forces. As the speed of the moving particle-laden airstream slackens the heavier particles are first to fall to Earth, the lightest are carried furthest. The result is 'wind-sorting'. Sand will be carried short distances in strong winds, the loess-silt grade of dust considerably further and in lighter winds, whilst the clay particles may be carried indefinitely and disperse completely.

Wind may of course remove and redeposit organic debris, as when it eddies into corners and fills them with fallen leaves (which may decay there and begin the formation of a layer of humus), but its most spectacular effects are seen in connection with inorganic matter.

The removal and redeposition of materials by wind is of the greatest importance both in the erosion and in the deposition of strata. Immediately the surface of the ground is stripped of its vegetation, which acts as a protection, it becomes open to erosion by wind. Enormous quantities of earth can be removed in a short space of time and the land-surface rapidly lowered—the 'dust-bowls' of the New World provide examples of wind-erosion following the destruction by man of natural vegetation.

It should be noted further that sand and dust-laden winds carry within themselves the tools for further destruction, for the surfaces of the hardest rocks break up when they are subjected to continued bombardment by small particles. Buildings as well as cliffs can often

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

be seen to be pitted by swirling dust and sand (Plate IV), and in their decay such cliffs and stones make their own contribution to the material available for transport by the wind.

In arid conditions surface stones—including implements—not infrequently acquire a 'desert polish' as a result of the continued passage over them of wind-blown sand. When the wind blows for long periods in the same direction the upper surfaces of stones lying on a sandy desert are sometimes so carved away as to present two upper faces inclined to each other like the two sides of a ridged roof. Such stones are called *dreikanters* and have sometimes been mistaken for human artefacts.

Whilst wind is responsible for spreading the pollen and seeds of many plants (including trees), if sufficiently strong or prolonged it is also extremely destructive of vegetation. Many seedlings are able to survive only in the shelter provided by other vegetation: once this has been removed regeneration of the natural plant cover is slow and sometimes impossible.

At Peacock's Farm in the East Anglian fens, where a Mesolithic site was excavated,[1] 'the even scatter of the abundant sand grains' in the 'black layer' in the lower peat which lies up against and upon a sand ridge 'suggests wind-carriage at the time when sandy areas, uncovered by vegetation, were present'. Here then is another example to show how the presence of wind-blown material may indicate the local environment.

Wind from off the sea may carry salt spray well inland and so be responsible for the destruction of plants not specially adapted to resist.

The sea provides sand which is blown by the wind into sometimes enormous dunes. The Culbin Sands on the Moray Firth are dunes which in a strong wind 'flow like water'.[2] A prevailing south-west wind has caused a constant flow in a north-easterly direction so that within comparatively recent times a mansion, estate, and sixteen farms have been buried, whilst the drift of sand has been strong enough to force the River Findhorn to change its course.

Some grasses, such as marram, can find root and sustenance in sand and may colonize sand-dunes. They may succeed in covering them and so in arresting movement by the wind, but where contours are steep and the movement of the sand often rapid the young grass tends to be overwhelmed before it is established. At Culbin the Forestry Commission has resorted to 'thatching' the dunes with brushwood, broom,

[1] J. G. D. Clark, H. and M. E. Godwin, and M. H. Clifford, 'Report on recent Excavations at Peacock's Farm, Shippea Hill, Cambridgeshire', *Antiquaries' Journal*, XV, pp. 284–319, 1935.

[2] *Britain's Forests—Culbin*, The Forestry Commission, 1949.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

and birch-thinnings, which allows the immediate planting of young fir and pine trees: eventually the thatch decays and, with fallen leaves (needles), helps to form a thin humus and soil.

In natural circumstances a carpet of established grass may provide a place for young trees to grow. Once so established the tree-cover has a chance to remain, regenerate, and hold the sand, but always swirling wind may destroy the thin turf and again expose the sand. In the Outer Hebridean Islands of Scotland sooner or later 'in a place where the wind has broken the turf, you will come upon a large heap of periwinkle shells, bones and potsherds'.[1]

The effect of wind-sorting can be very confusing to the archaeologist, for, with the lighter material blown away, heavier matter originally laid down in and upon successive layers all falls to one level.

At Udal,[2] 'where the ruins of the mediaeval buildings can be seen on the tops of sand-dunes which cover several (much earlier) wheel-houses . . . fragments of pottery lie in middens exposed by wind . . . In some places the weathering has caused wheel-house and mediaeval pottery to lie on the same heap. Where this occurs, the later pottery looks very much more primitive and as if it came from an altogether earlier culture than that of the wheel-houses.'

At the long-occupied site of Jarlshof in the Shetland Islands, sand layers are seen to cover successive layers of peat-ash dumped as refuse: these sand layers are merely the result of the movement of sea-sand by wind.

Mere weight of piled-up wind-blown material will destroy obstructions such as walls in the path of the wind: on the other hand burial in sand-drifts has often protected archaeological material from erosion. The Bronze Age village of Skara Brae, Orkney, and the Roman town of Lepcis Magna in Tripoli are obvious examples: at the latter site even the roofs of the baths were preserved.

Though in detail possibly arguable, conclusions reached with regard to wind-action in the Fayum[3] are of interest: at a certain place 'the ground is covered by deeply ripple-waved blown sand . . . Querns and rubbers in sandy limestone and grit abounded: many lay upon the waves of drift sand: others were so frequently upside down as to attract attention: this very general occurrence of querns and heavy stones on the surface of sand accumulations is to be attributed to the relentless pressure of myriads of wind-driven grains. These drive down under any concavity in the object, pile upon the windward side until sufficient sand has accumulated to lift it, first to a vertical position and

[1] T. Lethbridge, *The Painted Men,* Andrew Melrose Ltd., 1954.
[2] Lethbridge, *op. cit.*
[3] G. Caton-Thompson and E. W. Gardner, *The Desert Fayum*, Royal Anthropological Institute, p. 83, 1934.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

finally to capsize it. On a large scale the power of this process was seen in the overturning of great blocks of concretionary sandstone near Dimai: many were found tilted on edge before the final "push" was given. This upward lift of the sand grains undoubtedly accounts for the position of the querns.'

It may be added that the removal by wind of light material on the lee side of any object would undoubtedly assist in such a process of reversal.

A phenomenon in the Fayum depression, which itself probably resulted from wind action, was the appearance on an old strand line of numerous low hummocks. These, say the investigators, were capped by hippopotamus bones as well as by stones, the hummocks being '. . . created by the protective capping given to soft beds by a harder substance. The same result is produced also by clumps of dead vegetation on former shore-lines: sections cut in these show them to be essentially of blown or washed sand piled against roots and branches now sub-fossilised and erosion resistant.'

It is thought that both in the Fayum and at Kharga Neolithic men sank their hearths or fire-holes into the ground and lined them with limestone blocks. But gradual lowering of the desert level as a result of wind-erosion has preserved the hearths as stone-capped mounds.

Whilst the wind may erode and deposit its burden unevenly, in general it is a leveller: wind-blown material—sand, soil, leaves, snow—will fall into even slight depressions and there lie undisturbed by the wind blowing across the edges of the holes. (Incidentally, powder-snow in minor hollows, when the surrounding level ground has been blown clear, has more than once shown, especially clearly in air-photographs, the presence of unsuspected monuments.)

But material blown into a hollow rarely conforms in structure with the material into which the hollow has been excavated: it was for this reason that Ptolemaic irrigation channels which had been completely masked by blown sand were revealed after a shower of rain when seedlings sprouted luxuriantly along the line of the old channels.

Wind erosion has its greatest effect when the surface of the ground is dry, for where no moisture holds the solid particles together they can be moved and removed individually.

It has been concluded from a number of circumstances that at the end of the Neolithic period in southern Britain the climate was warmer and drier than that of today: at the present time the area enjoys an 'Atlantic' climate with temperate winters and mild summers, but at various times in the past the climate seems to have been more 'Continental', that is, with severe winters and hot dry summers. Such a 'Continental' climate involves summer droughts, which especially affect

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

porous ground: the vegetation dies and light soils and sand become mobile.

The conclusion is confirmed by the consistent finding of wind-blown soil as a stratum deposited *after* the digging of ditches of the Neolithic period in England and *before* the erection of later Bronze Age barrows. This has been interpreted as meaning that not only were there hot dry spells but also that some form of farming activity was probably uncovering and loosening the soil and so making it vulnerable to wind action.

This is less marked in areas with an Atlantic climate but it may be noted here that ideas concerning a climatic optimum may vary. In some areas human life may be more comfortable when conditions are damper than when they are more arid: this happens in the Ukraine, which has changed back and forth from dry steppe to cultivable parkland. On the other hand, a Briton might regard a slightly warmer, drier climate than that of the present day to be desirable.

Aridity, however, is not always the result of climatic warmth: extreme cold will also lock up moisture. The great blanket of originally wind-sorted and wind-blown loess which extends across Europe and into China originated in the moraines and glaci-fluvial sands surrounding Pleistocene ice-sheets, in the gravels of rivers, and in the screes of hills upon which frost erosion (see Chapter 5) was at work. The loess continued to be blown across the ground until the speed of the wind was reduced and until its movement was arrested by growing vegetation.

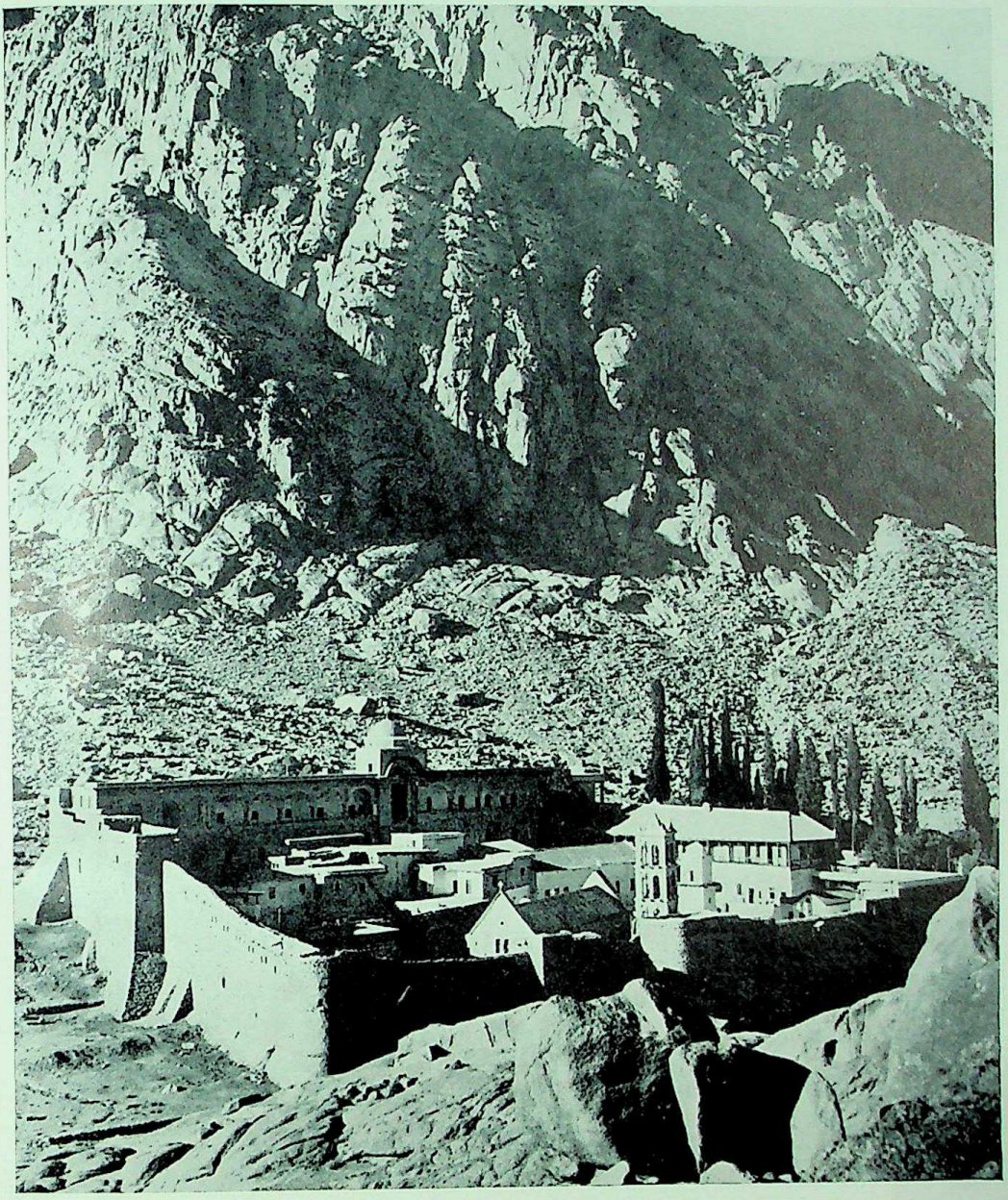
This loess has a characteristic grain size predominantly between 0·002 and 0·06 mm. (the 'silt grade') and successive glacial phases in the climate of northern Europe have provided several successive layers (see page 39).

The finding of a buried stratum of wind-blown material may therefore help the archaeologist not only in reconstructing past climates but also in suggesting a *terminus post* or *ante quem*.

It is characteristic also of loess that, when exposed as a vertical section, it tends to separate from itself along vertical divisions and close examination often shows that the loess deposit is perforated vertically by tubular holes. These tubes were originally occupied by the stems of grasses—now disappeared—for it was vegetation which caught the drifting dust and anchored it.

It is as well for the archaeologist to remember this tendency to vertical cleavage of horizontally stratified loess and brickearths (see page 51), for a block which has fallen, say from the side and into the bottom of an old well or pit, when seen in section may sometimes have the appearance of a deposit composed of tilted layers.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh



1. St Catherine's Monastery, Sinai, set amongst rocks which have been shattered largely as a result of temperature changes. The loose scree at the foot of the hills is composed entirely of fragments of rock which have fallen from above.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

II. Sun-dried mud cracked vertically by contraction on desiccation; the upper layers are beginning to curl and peel off.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

The thickness and distribution of the loess are in themselves informative, for an increasing spread and depth south-eastwards indicate that at the time of its deposition the prevailing winds were from the north-west and that little material was available for transport by the wind in the western parts of Europe, whose local climate was always more damp and Atlantic than that of central and eastern Europe.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

4

Rain

THE WORK OF rain in stratification is two-fold—chemical and mechanical. Let us consider the mechanical first.

A gentle shower will have little mechanical effect, for each droplet will find its way into the ground without seriously disturbing its surface. A slightly heavier shower will beat the ground and flatten any loose soil, and if the downfall continues the surface will become waterlogged and the rain-water will have to run off the surface, always downhill. The water in so running off and 'finding its own level' will carry some material with it.

It is sudden downpours which cause most erosion. A winter torrent is capable of carrying very big loads which, eddying, can wear kettle-holes in hard rock, whilst a sudden spate can change a river's course. At Lynmouth in Devon it was a sudden torrent which caused disaster in 1952 and strewed the town with boulders weighing many tons.

A thin spread of stones seen in section in an excavation cutting or a quarry may mean no more than that there was a downpour which carried these stones to the site and washed the lighter material further away. However, the beating of the ground's surface by rain before the downpour may so compact it that stones protruding from and lying on the surface are sometimes moved without the compacted smaller material being disturbed. In the ploughed fields at the foot of the North Downs one sometimes sees, after a heavy storm following earlier beating rain, rivers and deltas of surface flint-stones only. Quite obviously some materials and man-made structures will withstand the destructive effects of rain longer than will others, sometimes with spectacular results.

The power of movement by surface-water is proportional to the rate of the flow: a slow trickle will move (within itself and apart from what may float on it) only the finest grains of the clay grade (grains of less than 0·002 mm.) whilst a torrent may move enormous boulders.

It should be noted that water also acts as a lubricant and assists one mass of earth to slide over another: this is one of the ways in which it is responsible for land-slips on all scales and for the spreading and cambering of any material which the force of gravity is tending to move.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

In May 1957 a few hours of heavy rain in the hills behind Hong Kong were enough to engulf motor-cars in the streets of the town up to their wind-screens in water-borne silt (Plate V). This exemplifies all rainwash stratification, for the dual nature of the process is obvious: tons of earth were deposited in the streets—tons of earth were eroded from the hills.

Constant dripping alone may wear away a stone and the drip from roof-eaves may excavate an appreciable trench in the ground below them, but moving water, like wind, may carry within it abrasive matter to assist in its destructive work: many rocks may be seen to be highly polished merely as a result of the constant passage of trickles of rain-water.

As will be described in Chapter 8, which deals with the larger volumes of water concerned in streams and rivers, as soon as the flow decreases or slows down, eroded material borne by it is deposited and so forms the material of new strata.

Benjamin Harrison, the father of 'eoliths', was an observer of stratification in progress and wrote:[1] 'The drift below Drain Farm was the result of a great rush of water caused by the heavy rainstorm on 31st July last (viz. 1888) when about three inches of rainfall were recorded in two hours. A gully was cut out no less than five feet in depth, and this fact is so striking an example of the great power of denudation possessed by a rush of water that Prestwich [Professor Sir Joseph] thinks that it should be recorded. I was afterwards informed of another gully cut out in the road near Fox and Hounds Inn, Darenth Wood. This gully was stated by the highway surveyor to be thirteen feet six inches in depth, over 1000 (cubic) yards of debris being washed down.'

Such deep gullying is not very often noted, though a series of very ancient consecutive gullies were observed buried deep in the heart of the tell at Jericho, each gully in its turn filled by human debris and then subsequently re-excavated by a downpour. Incidentally whilst this little town was occupied the tell-mound continued to grow as a result of the accumulation of materials brought to the spot by man, but when the site was cursed and abandoned at the time of Joshua, rain and wind were free to erode it: little if anything thus remains of the upper levels and of the walls round which Joshua marched.

The Roman villa site at Lullingstone in Kent, on the other hand, gradually became buried in rain-washed material. Being at the foot of and on the side of a steep hill it has been subject to recurrent torrents and trickles. Much material must have washed over it and away from it, but, in spite of continuing surface erosion, by the time of the

[1] Extract from note dated 14 August 1888 quoted on p. 135 of *Harrison of Ightham*, by his son Sir Edward Harrison, Oxford University Press, 1928.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

excavations in 1949 some three feet of 'hill-wash' had accumulated upon the fourth-century tessellated floor since the time of Edward II (1307–27), a coin of whose reign was found but a few inches above it.

To explain the absence of hill-wash dating from the period prior to Edward II a working hypothesis was formulated suggesting that some sort of barrier existed uphill which held up the soil-creep until that date: it is interesting to note that walls parallel with the contours of the hillside have since been excavated and there is evidence which suggests their having finally collapsed only at a late date.

Here is a good instance of a knowledge of the *processes of stratification* (as opposed to a knowledge of strata *in situ*) having assisted the excavators not only to interpret but also to predict.

The year 1956 provided, at the same site, a further instance of the effects of a single downpour of rain. A small 'lake' seems to have formed in a field on level ground at the top of the hill and then, overflowing, to have cut away its bank. Solid matter was largely held on the hillside by vegetation but fine material found its way downhill with the flood which swamped the excavators' trenches and filled them with fine silt to a depth of some two feet.

It will be seen that whether an archaeological site is to be washed away by rain or covered by rain-washed materials is dependent upon several factors—obviously the annual rainfall first but also by its position in relation to the natural flow of surface-water and the resistance to erosion of the rocks forming any hill above the site which might provide transportable matter for rain to move.

Rain-water is a major cause of decomposition when once it finds an entry into any form of building. Rising by capillarity from the ground in structures without damp courses it will soften and destroy plaster and even stone: mud and adobe walls are rapidly disintegrated as soon as protective roofings and surfaces are impaired. Perhaps the most destructive effects, however, are achieved by successive wetting and drying: this suggestion especially applies to wood where the consequent alternate swelling and shrinking probably account for a greater amount of disintegration than does bacterial decay and damage caused by moulds and fungi. Differential expansion and contraction as the result of wetting and drying rapidly destroys most building materials and it is often the re-crystallization on drying of gypsum previously dissolved by rising damp which pushes plaster facings away from brick and stone walls. As it falls all such disintegrated material goes towards making those often datable strata which principally concern the archaeologist.

The foregoing paragraphs have been concerned largely with the erosion and the deposition of new strata resulting from the purely

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

mechanical effects of rainfall. Just as important to stratification are the resultant chemical actions.

A great many substances are soluble in water and are thus washed away from the surface of the ground, but the power of rain-water to dissolve is greatly increased by the inclusion in it of CO_2: this gas, exhaled by all living matter into the atmosphere, becomes dissolved in the falling rain during its passage through the air and the result is the formation of a weak acid—carbonic acid.

Whilst local rainfall in some areas is so slight as to have little effect—for example it has been insufficient to dissolve the laminated Pleistocene salty deposits, the Lisan Marls round the Dead Sea—elsewhere the chemical effects have been very considerable.

Excavation of many Bronze Age barrows and earlier Neolithic banks on the Chalk of southern England has led archaeologists to conclude that several inches of the ground's surface have been completely dissolved and removed since the erection of these structures, for solid undisturbed chalk is very often met with at a higher level under the protecting mound than in the surrounding country where no such protection is available.[1]

Chalk blocks packing the sockets on the weather side of the upright stones at Stonehenge were found to be much more disintegrated than similar blocks on the lee side: this difference was attributed to the continued trickling of water down that side of the stone which most frequently faces the rain.

The most notable effect of chemical weathering, however, is the production of 'soils' whose natures vary according to several independent factors, of which one is climate.[2] A soil is simply the weathered upper portion of a natural rock, but the process of this weathering may give rise to differently coloured zones in the ground which can be mistaken for separately and even humanly deposited strata. Such belts—or 'horizons'—are most readily seen on ferruginous sands and sandstones, though similar horizons are to be found almost universally on well-drained ground.

Let us take as an example the Greensand of southern England. The natural colour of the rock is greenish because of included glauconite, but exposures showing the original colouring are rare because many thousands of years of percolating rain have carried down oxygen and this has resulted in the transformation of the green glauconite in several feet of the upper levels into limonite, which has a yellowish-red tinge.

Upon this yellow sand more recent weathering has usually produced

[1] A recent example was provided by Dr Isobel Smith's excavations through the Neolithic banks at Windmill Hill, Wiltshire.

[2] I. W. Cornwall, *Soils for the Archaeologist*, Phoenix House, 1958.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

a soil known as a 'podsol' (the Russian word for 'ash' being used owing to the colour of the belt of greyish-white material which occurs in these soils). At the surface is a black humus of decaying vegetation, which itself produces humic acids: these acids together with acid rain-water trickle down into the ground dissolving and washing away from a belt below all but the insoluble greyish-white quartz grains in the sands. The material washed out, or 'leached', from this horizon is normally then redeposited in an uneven band lower down in the sand

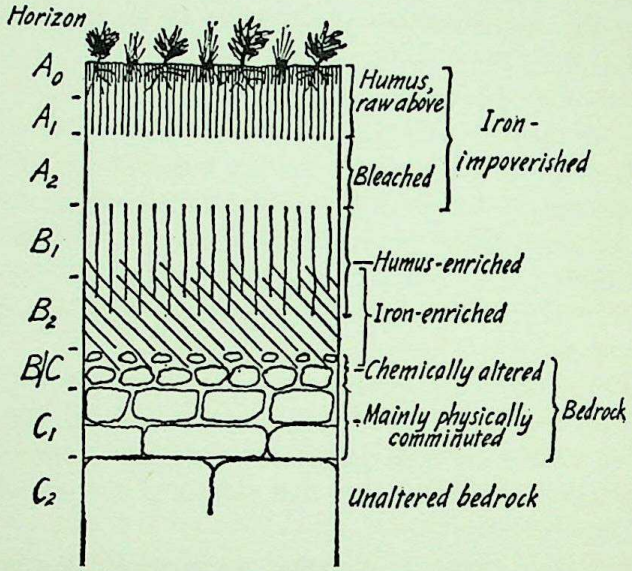


Fig. 2. This diagram shows how natural 'weathering' by percolating water may result in the production of differently composed layers which may have the appearance of separate deposits.

when less acid ground-water is encountered, sometimes immediately below the grey-white band but more often a few inches below the surface of the yellowish parent sand. The side of a trench cut into such a soil then appears very much as shown in Figure 2.

Such differently coloured horizons formed *in situ* should thus obviously not be confused with separately deposited strata, nor the redeposited humic and other matter with an occupational level or an ancient and buried layer of turf or peat.

Somewhat similarly formed are the black bands and streaks sometimes to be seen in the sides of gravel pits, particularly where these gravels lie upon chalk or limestone. Many gravels have been deposited one layer upon another, but a black layer in such a gravel is unlikely to represent the remains of a buried turf. It is more likely to prove to

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

be a deposit of manganese resulting from chemical weathering of the gravel long after its original deposition—for dendritic manganese is present in most limestone. This dissolves in acid solutions and is re-deposited in water bearing calcium carbonate—hence its appearance at what is or was the level of the ground-water.

Elsewhere calcareous matter removed from surface levels may be redeposited as nodules and coatings when the descending water, laden with calcium compounds, reaches an already saturated water-table.

It seems that rain-water was responsible for dissolving a capping of gypsum from the original surface of the banks at Thornborough Rings, and for carrying the material to a lower level.[1]

But substances leached from upper layers are not always redeposited at a lower level—many are completely removed by percolating water—nor is the appearance of the deposit always changed by the process. To the eye the whole of the material may appear more or less uniform even where a chemical analysis shows that the composition at successive levels is different.

At the well-known section at Wallertheim in Germany it is partly the absence of soluble minerals at certain levels in the loess blanket covering Mousterian implements which enables them to be dated. Three layers of identical wind-blown loess were found one upon the other, but they could be distinguished because of 'weathering horizons'.

Dry periglacial winds piled up a first layer of loess over the implements, cold conditions and deposition then ceased, and a subsequent warm wet period provided rain which dissolved calcareous minerals and removed them from the upper part of the loess. Later more wind-blown loess covered the site, burying the soil so formed, and in its turn this deposit had its upper part decalcified by rain-water. The process was finally repeated for a third time.

Professor F. E. Zeuner has interpreted the three periods of deposition as corresponding with the three cold maxima of the Last Glaciation, the first two weatherings as belonging to the intervening warmer periods and the last weathering (from the modern surface) as being related to the post-glacial period. The underlying implements must therefore, he argues, have been made by man before the onset of the Last Glaciation.

The percolation of acid surface-water is also responsible for much of the stratification of deposits on the floors of the caves in which many Upper Palaeolithic artefacts are found. The majority of such caves are found in limestones, which, by reason of their composition, are particularly subject to solution by acids. Trickling down fissures and along bedding-planes in these sedimentary rocks the rain-water

[1] See I. W. Cornwall, *Soils for the Archaeologist*, Phoenix House, 1958.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

gradually enlarges its paths and hollows out the cave itself. The bulk of the lime thus dissolved is carried away completely and is lost in the water of the water-table below the cave.

As soon as air enters the cave, however, it is likely that some of the lime will be redeposited and this redeposition may give rise to strata of considerable thickness. As the calcium-saturated water drips from the roof of the air-filled cave some part of it evaporates and, in doing so, releases some of its content of carbon dioxide: the result is deposition of calcium carbonate on the cave roof at the point where the dripping began. The process continues and eventually long columns of stalactite grow downwards from the roof. As the dripping water runs down the walls of the cave or spreads on the floor further deposits of calcium carbonate are laid down—in this case being termed stalagmite (or, as some prefer, 'flow-stone').

Such stalagmitic floors may attain several feet in thickness and effectively seal any earlier strata. Occasionally the presence of a floor can be related to a particular phase of the contemporary climate, but in view of the fact that so many contributory factors are involved—configuration of the ground surface, accessibility and flow of air, temperature, pressure, etc.—no general principles can be laid down: nor can any rate of deposition in terms of years be calculated since, given the right conditions, accumulation may be comparatively rapid. At Caldey Island, Pembrokeshire, several inches of stalagmite were found to overlie pottery of the British Iron Age.

These stalagmite floors are often extremely hard and have occasionally been mistaken by excavators of superimposed deposits for solid rock. Such was the case at Font Echevade where flint implements were eventually discovered below a floor which was at first thought to be the rock bottom of the cave.

The stalagmite floors may sometimes sag and slump as material is washed and dissolved away by water which has found its way beneath them.

When angular rock fragments are cemented together by stalagmitic deposits of this kind (either within a cave or elsewhere) the resultant concretionary deposit is known as 'breccia'. In such a breccia were found the remains of 'Rhodesian Man'. When rounded pebbles are cemented in a matrix the deposit is known as a 'conglomerate'.

The purest of limestones includes some impurities, and as the calcium is dissolved these included clays and sands are freed: finding their way to the floor of the cave they help to form layers of 'cave-earth', which may attain many feet in thickness. In their formation they will seal below them artefacts and bones within the cave—though in the conditions obtaining in an actively forming cave they themselves may

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

occasionally be subjected to further movement or be supplemented by materials washed into the cave from outside.

Not always will calcium carbonate dissolved in percolating water be redeposited within holes, caves, and fissures in the rocks, but may find its way to the surface of the ground again in the still saturated water emerging as a spring. In this case deposition of the calcium will take place round the spring's orifice as soon as the water meets air and evaporation takes place. The result is layers of 'tufa'—a concretion of calcium carbonate. Tufa is normally loose and porous but may be more compact if the water depositing it flows slowly. 'Travertine' is such a compact form, which may provide good building stone. Evidences of discontinuity in the deposition of tufa can sometimes provide important evidence of changes in the volume of a spring and hence in the local rainfall and climate. This was the case at Ehringsdorf in Germany:[1] the upper part of the succession of strata is as follows (from surface downwards):

(a) wind-blown loess—deposited during the second dry cold phase of the Last Glaciation;

(b) a travertine layer containing remains of a flora and fauna typical of a cool to temperate climate, that of an interstadial rather than of an interglacial period;

(c) another layer of loess, deposited during the first cold maximum of the Last Glaciation;

(d) a lower travertine layer which contained remains of Neanderthal man together with those of a flora and fauna indicative of a climate with a rainfall higher than that of today.

Particularly interesting spring- and wind-deposited strata were found at Kharga Oasis in Egypt[2] where there are evidences of fossil and dead springs. Implements referable to Acheulean, Levalloisian, Middle Palaeolithic (Pre-Sebilian), Aterian, Capso-Tardenoisian, and Neolithic industries have all been found *in situ*, and the nature of the deposits in which they were found provides evidence as to the climates contemporary with their making.

The series of deposits may be summarized as follows (in this case the sequence is given in the order of formation, viz. with the lowest stratum first):

(a) a massive crystalline tufa was formed possibly as early as Pliocene times;

(b) a period of heavy rainfalls resulted in the erosion of valleys cutting into the tufa;

[1] F. E. Zeuner, *The Pleistocene Period*, Ray Society, 1945, pp. 67–9, 265.
[2] G. Caton-Thompson, *Man*, XXXII, pp. 129–35, June 1932.

 CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

(c) the valleys became filled with angular breccia and there was a long dry period which left no signs of the presence of water;

(d) rain returned to the area and encouraged vegetation and the growth of molluscs, whose shells are found. Cellular tufas were formed over the breccia and associated with them are Acheulean implements;

(e) water-strewn gravels were deposited on the plateaux: running water cut valleys into the gravels and Acheulo-Levalloisian implements were covered by deposits of tufa;

(f) the climate became drier but tufa continued to be deposited—over 'Pre-Sebilian' tools. To quote from *Man*: 'the mode of formation of these tufas was found to be the result of ponding up of the primary valleys. The boulder barrages were identified in several cases with the ponded tufas up-valley. Pre-Sebilian man frequented the shores of such spots and tool collections were made from sub-tufa silts laid down in the ponded areas';

(g) the formation of tufa ceased and the streams became less copious but they continued to cut channels into the floors of old valleys. As they cut down they left terraces of gravel on the flanks of the valleys (see pages 69-70). In the upper gravels were found Pre-Sebilian implements: as the streams continued to slacken a thin bed of silt formed on top of the gravel (and in it was a fine Aterian flaking floor);

(h) man abandoned the site of these earlier finds—presumably because of a lack of water—and Capsian and Capso-Tardenoisian implements are found, instead, on the Libyan plateau around, or buried in the silts of shallow clay pans.

Tools of the Aterian culture are also found on the plateau connected with spring deposits and they are sealed over by a sandrock of aeolian origin. Again quoting *Man*, 'the formation of these sandrocks was the final stage in the history of all the fossil springs known to us and, as the deposit is consolidated dune sand, it may be inferred that desert conditions obtained prior to the date provided by this site'.

It should perhaps be added that many of the flints from Kharga Oasis are covered with a glass-like film of transparent redeposited silica which simulates the polish given to stones by wind-blown desert sand. Similar silica glazes occur on implements in Jordan and elsewhere: they are the result of the deposition of colloidal silica from water into which it had been absorbed when the water was hot—either as a result of the sun's rays or because of its having issued from the earth as a hot spring. The colloidal silica has been deposited in hydrated

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

form in continuity with the flint of which the implements are made.

The effects of rain, as has been seen, are mainly destructive but in one or two ways it helps to preserve. It assists in the decay of metals but iron rust formed in contact with bone will turn bone phosphorus into insoluble iron phosphate and something may remain.

Water as has been said is also an essential agent in the formation of many natural concretions. Of the earthen approaches to a Roman bridge, Kenny wrote:[1] 'The materials of which the abutments are made is the same gravel as was used for the metalling of the road. On account of its high ferruginous content it binds well, and has set hard as concrete, with the result that the outlines of the bridge-heads are well-defined and the angles sharp.'

[1] E. J. A. Kenny, 'A Roman Bridge in the Fens', *Geographical Journal*, No. 82, 1933, p. 434.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

5

Frost

THE TWO-FOLD EFFECTS—denudation and deposition—of changes in the Earth's surface caused by sun, wind, and rain have been discussed. Now let us turn to the effects of extreme cold.

The effects of contraction owing to cold have been mentioned on page 25: far more destructive, however, are the forces of expansion.

It is well known that water expands upon freezing so that ice fills a larger volume than that occupied by the water of which it is composed. The transformation into ice of water held in crevices in rocks and within the material of the rocks themselves (and other materials) is responsible for rapid and extensive denudation, since immense forces tend to explode the material from within.

Expansion, forcing flakes and fragments off a nodule of flint (or other rock) by pressure from within, often results in the production of stones so chipped and scarred that, superficially, they resemble man-made implements: a close examination, however, will show that the scars of flakes removed by a blow from outside the core present, in fact, a characteristic and very different fracture surface.

Flint which has been exposed on the surface of the ground is usually not only pocked with hollows from which frost has forced out 'pot-lids' but is also full of frost-caused cracks. It was probably because of these flaws and the resultant uncertainty of the direction of intentional flaking that primitive man began mining for flint which lay at such a depth in the chalk as to have remained protected from temperature changes.

The screes found on the slopes below exposed crags in cold and temperate areas, although very like those illustrated in Plate I, are formed almost exclusively of fragments which have fallen after being forced from the parent crag by the expansion of ice. Such scree material may become an important element in the formation of new strata, but it is not only the exposed crag which is shattered by frost: even small pebbles are split. In England almost every stone on the surface of a ploughed field has at least one face which shows where frost has reduced its size by the removal of a fragment.

Activated by gravity and sometimes also by flowing water, the shattered fragments move gradually downhill. In certain circumstances,

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

however, the movement can be rapid and extensive. This is particularly the case when, as in peri-arctic areas, the ground in winter is frozen to a depth of many feet. When the warmth of early spring and summer melts the top few feet and the overlying ice and snow, the melt-water is prevented from draining away completely by the still frozen, and thus impermeable, layers below. The upper levels of the ground, including rock-screes, mud, sand, and in fact any superficial materials, therefore become saturated and form a sludge which can slither downhill on even very gentle slopes. To this process of movement is given the name *solifluxion*; it can affect extensive areas. Cold conditions, however, are not essential to soil movement. Given sufficient lubrication by moisture almost any surface deposit may move downhill under the effect of gravity. Where fairly large masses move suddenly the term *land-slip* is often used whilst gradual and less spectacular movement is described as *soil-creep*: neither process should be confused with the kind of solifluxion described above.

A field-note made by Benjamin Harrison is apposite. On Christmas Day 1899 he wrote:[1] 'Rain in the night, roads and land very wet and dirty. Even the sand fields near the Borough Green Roman finds are one mass of slush, the frost in the ground preventing the water from sinking away. This fact seems of especial interest, as a heavy rainfall following frost would accelerate sub-aerial denudation, even in absorbent sand.'

During glaciations, and particularly as the ice-sheets melted and retreated, extensive deposits of solifluxion materials were laid down and are often found to blanket earlier features and deposits. At some sites, downward-moving sludge layers interdigitate with layers being deposited by different agencies at the bottom of a slope. Such is the case at Brean Down in Somerset[2] where successive pourings down a seaward-facing slope alternate in places with sands blown from the sea's edge.

Normally solifluxion deposits, full of frost-shattered stones, are devoid of any bedding and show, rather, evidence of turbulence—an example is provided by the 'upper gravel' at Swanscombe (see page 68) —but where the material and conditions have been suitable, a rough stratification may sometimes be seen. In the well-known cliff-face at Black Rock, Brighton, Sussex, the material which lies above and seals the 25-foot raised beach is seen to have a rough layering: 'streams' of semi-liquid sandy material (carrying with them large blocks of quartzite from inland) appear to have spilled over a chalk cliff and to have built up successive layers on the beach below.

[1] Sir Edward Harrison, *Harrison of Ightham*, Oxford University Press, 1928.
[2] A. M. ApSimon and D. T. Donovan, *Proceedings of the Bristol University Spelaeological Society*, Vol. 7, No. 3, 1956.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

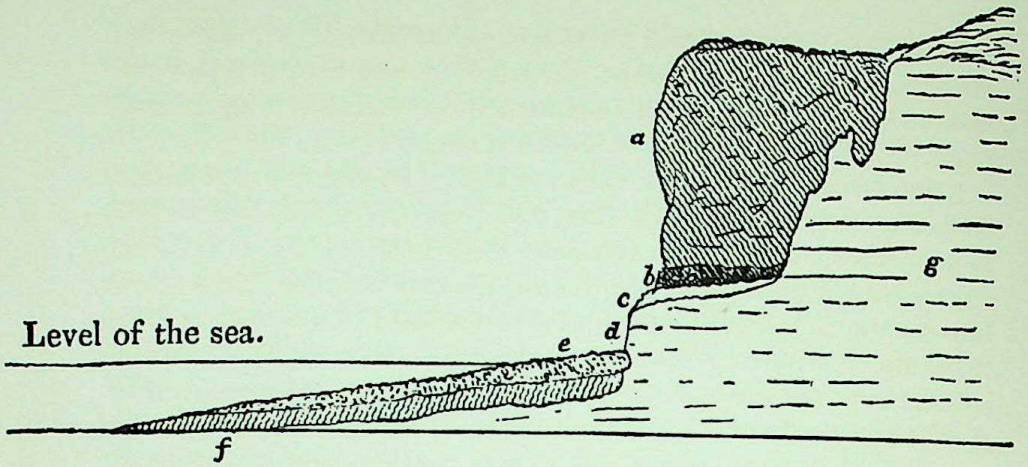


Fig. 3. Gideon Mantell's diagram of the section through strata at Black Rock, Brighton. The 'Elephant Bed' (a) is a solifluxion deposit formed in periglacial conditions above an earlier beach deposit (b).
a. Elephant bed. *b.* Ancient shingle. *c.* Ancient sand. *d.* Base of cliffs of chalk rock. *e.* Modern beach. *f.* Modern sand. *g.* Chalk rock.

Gideon Mantell,[1] owing to his finds in it of Mammoth bones and teeth, gave to the Black Rock solifluxion layer[2] the name of 'the Elephant Bed' (Figure 3). It was he, too, who observed that the bottoms of many valleys in the southern English chalk are filled with shattered and unstratified flint and chalk derived from former surfaces. To such deposits he gave the name of 'combe-rock',[3] and it is strictly only to such deposits that this name should be applied; for similar deposits where the parent rock is other than chalk the name 'head' should be used. However, 'combe-rock' is often used to describe material which, though frost shattered, has not slid downhill, but has remained *in situ.* In once-glaciated northern Europe the upper few feet of almost every cliff are seen to be frost-shattered—a disturbance not to be mistaken, when excavating from the surface, for human activity.

In the chalk cliff between Brighton and Rottingdean may be seen a wedge-shaped area in which the chalk is shattered and comminuted, but still in position, with rows of flint nodules still continuous with those on either side in the solid chalk. The whole mass can be regarded as incipient combe-rock: washed out it would have left a steep-sided valley not dissimilar from the dry valleys so common in chalk country.

Once so shattered the upper levels of the 'solid' chalk are readily

[1] Gideon Mantell, *The Geology of South-East England,* 1822.
[2] Gideon Mantell, *Fossils of the South Downs,* 1822; Plate IV.
[3] *Ibid,* p. 277.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

gullied. The surface below the turf becomes rather unevenly dissolved. Such gullies and runnels when discovered during excavation of prehistoric settlements must not be mistaken for artificially dug drainage channels, or for other signs of human activity.

It will be found that when the solid rock sides and floors of ancient ditches are exposed by excavation, they are in very few cases exactly as they were left by the people who dug them. At any rate, where ditches have been cut into solid chalk, the original sharp right-angles between the undisturbed surface of the rock and the once vertical sides of the ditches have been destroyed and rounded by frost. Much damage is done in the first winter after the digging of a ditch and large quantities of dislodged material fall into the bottom. If the ditch is left open the process continues until, instead of being vertical, the ditch walls present, in section, graceful convex faces.

Even if the ditch has been filled in soon after it was dug the original faces will usually be found to have been destroyed by penetrating frost and also by percolating rain-water. In most cases therefore ancient ditches as they are now found are a few inches wider and a few inches deeper than they were originally (Figure 4, Plates VI, VII).

At low temperatures the solubility of some rocks is increased.

Outwash gravels and sands, which normally spread in delta-like fans from a point where melt-waters leave a glacier, are in some ways not unlike solifluxion deposits; being spread by moving water however they are much more clearly stratified. They are found as relics of glaciation in places now free of ice, and on level terrain they may extend over a wide area. Outwash gravels are normally archaeologically sterile but provide useful *termini post* and *ante quem* for implement-bearing deposits above and below them.

Glaciers and ice-sheets themselves are responsible for the removal and transport of enormous quantities of material. Constantly replenished by the falling of snow at their sources, they move slowly downhill and then, owing to pressure from behind, maybe for many miles across level country. As they thus pass through valleys they tear fragments and boulders of rock from the valley flanks and at the same time frost-loosened material falls onto their surfaces. Meanwhile, the base of the glacier is plucking at and incorporating in itself material from whatever surface may be crossed. Slowly all the accumulated material is ground and crushed and mingled and, as the glacier moves, becomes an abrasive. The ice, which at glacial maxima during the Pleistocene Ice Age covered much of northern Europe, seems to have taken the form of extensive sheets similar to those of the Ross Sea and the Greenland Ice-cap of today, rather than of individual glaciers, and therefore resulting deposits are laid in extensive strata; in non-

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

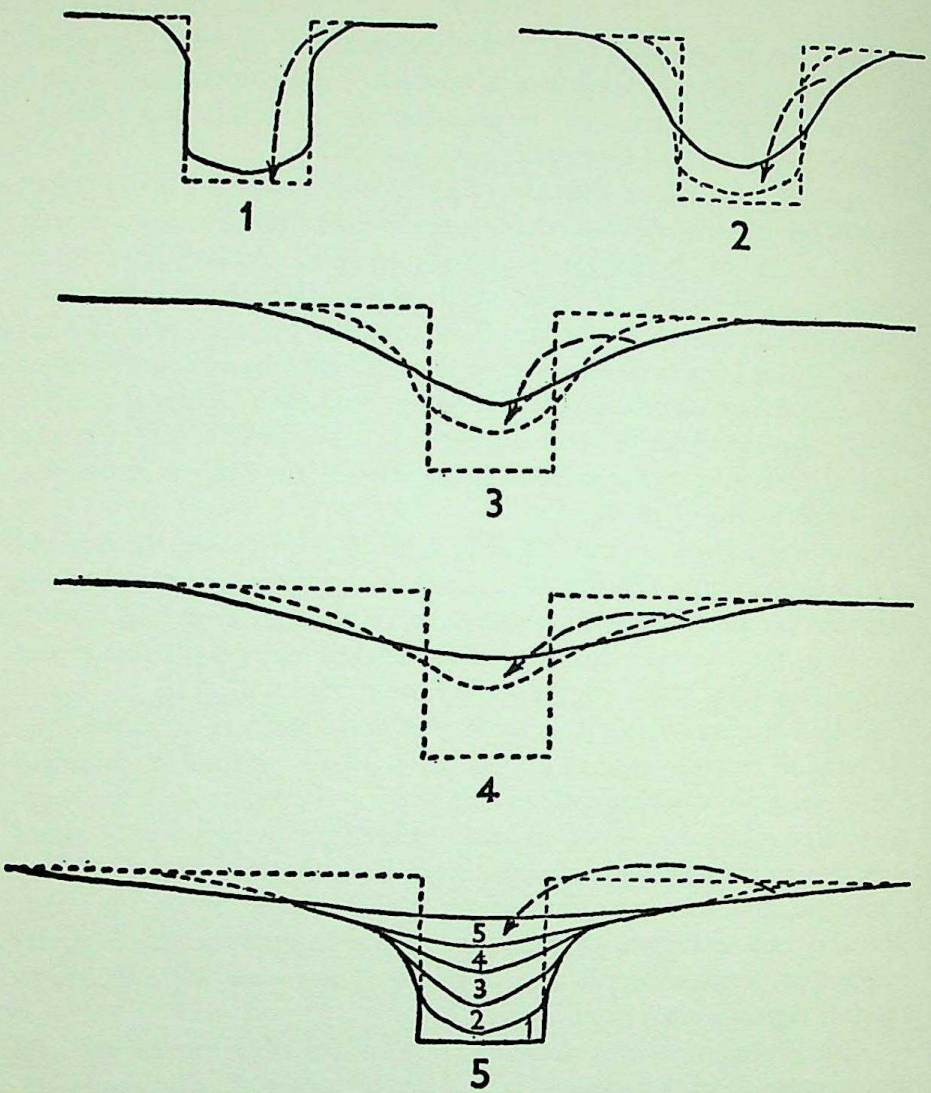


Fig. 4. In these diagrams number 1 shows how the upper lips of a square-cut trench are the first to fall in. Numbers 2, 3, 4, and 5 show how the sides are progressively eroded and the trench gradually filled in.

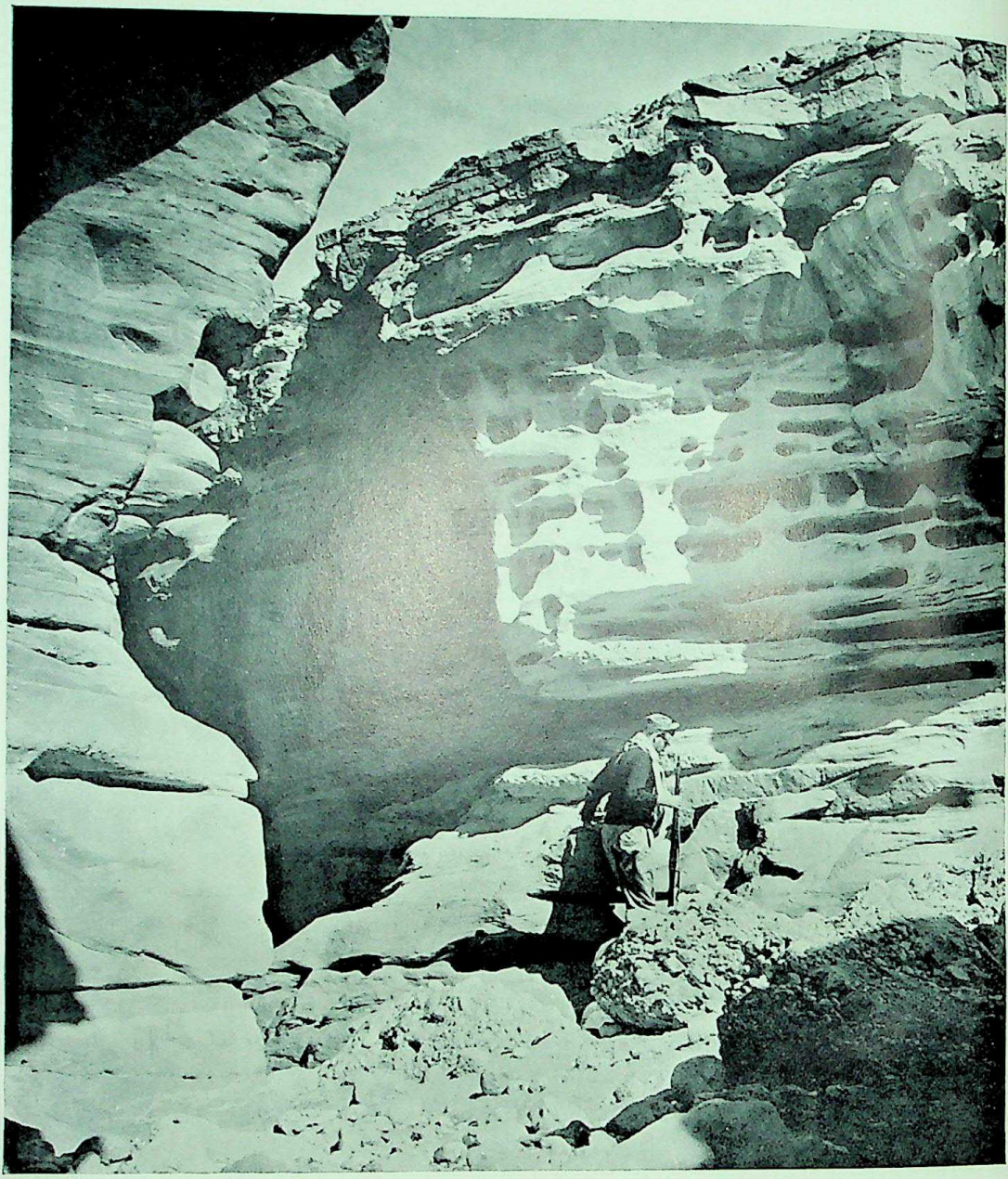
mountainous country they may completely blanket and hide former topographic features.

At the furthest extent of the glacier a long mound of tumbled rocks will be accumulated—its *end moraine*—and on either flank similar mounds, the *lateral moraines*. Such moraines may be of very considerable height—that left at Hunstanton on the east coast of England by one of the last glaciations shows as quite an appreciable ridge of low hills.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

III. The lower ends of these iron railings, originally fixed with lead into sockets in the wall below, have been destroyed by sulphuric and carbonic acids derived from the atmosphere, and by electro-chemical action.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh



IV. A sandstone cliff at Ras el Nakb, west of Akabah, showing how wind-borne particles erode solid rock. The softer and less compact strata are destroyed first.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

The principal component in the formation of glacial strata however is the layer of material borne within and at the base of the glacier—the *ground moraine*. When the ice melts and the glacier appears to retreat this material is simply dropped and all that tract of country once covered with ice will continue to be blanketed by a typical deposit—*boulder-clay*. The name implies what the reader will expect, namely, a compact deposit, in itself a stratum, but internally showing no signs of stratification: a matrix of fine clay carries within it rocks of many sizes and of many different origins. Extensive remnants of successive mantles of such boulder-clays, containing erratic stones from Scotland and Scandinavia, cover most of the British Isles north of the River Thames. Sandwiched between them may be deposits dating from warm inter-glacial periods which often, as at Hoxne[1] in Suffolk, contain human artefacts. It is the archaeologist's task, with the aid of the geologist, to refer each glacial deposit to a definite glacial period and so provide a relative date for the artefacts (see Figure 5).

The direction in which any portion of the ice-sheet last moved is often recorded within the boulder-clay itself, for stones are found to have aligned themselves with their longest axis parallel to the flow.

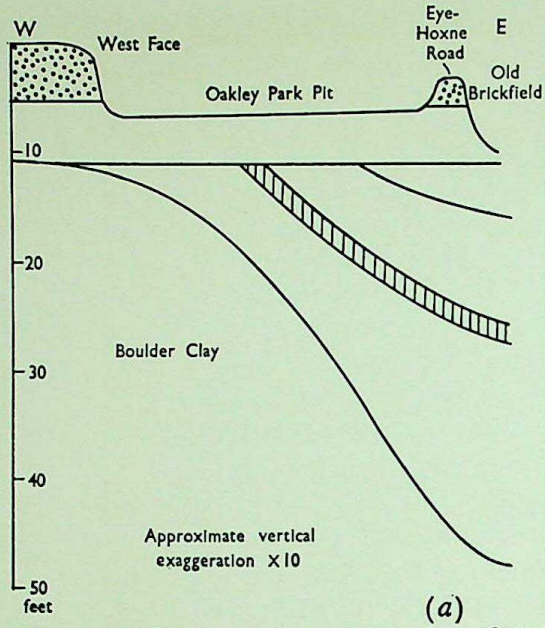
In mountainous country boulder-clays will be limited to the channels which formerly confined glaciers of the Alpine type; these channels may be partially choked. At Cae Gwyn in North Wales[2] the mouth of a cave in a valley side was occupied by prehistoric men who left flint tools on the floor of the cave. Subsequently the mouth of the cave became choked by a glacier and later by its boulder-clay deposit. Indeed, explorers of a different means of access to the cave system approached the deposit from inside the cave and were not at first aware that they had discovered a blocked entrance. Identification of the blocking deposit provided a *terminus ante quem* for the human artefacts.

Where ice-sheets and glaciers have melted one frequently finds *eskers* and *drumlins*. Eskers consist of sand or gravel which accumulated in melt-water channels either on the surface of or beneath the ice: they may survive for considerable distances as well-drained gravelly ridges on either side of which may be belts of boulder-clay and marshy ground. As such they provided obvious routes for the movement of the first people to settle the area after the retreat of the ice.

Drumlins are low hills which seem to have been formed in boulder-clay as a result of re-advancing ice-sheets riding over and moulding the existing clay deposits. By rising a few feet above wetter ground

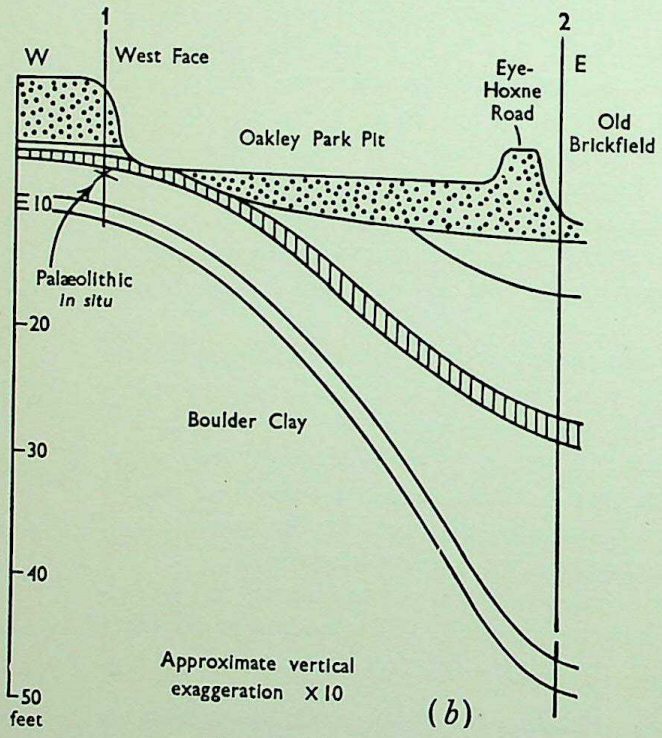
[1] R. G. West, 'The Quaternary Deposits at Hoxne, Suffolk', *Philosophical Transactions of the Royal Society*, 1956.
[2] D. A. E. Garrod, *The Upper Palaeolithic Age in Britain*, Oxford University Press, 1926.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh



Interpretation by Clement Reid		Interpretation by Reid Moir	
DEPOSIT	CLIMATE	DEPOSIT	CLIMATE
Palæolithic Sand (A)	?	Decalcified Chalky Boulder Clay	Glacial
Palæolithic Loam (A)	?	Brickearth	Temperate
Palæolithic Gravel B	?	Gravel	Cold
Black Loam C	Arctic	Loam	Arctic
Lignite D	Temperate	Lacustrine Beds	Temperate
Clay E	Temperate		
Boulder Clay	Glacial	Boulder Clay (Kimmeridgian)	Glacial

Fig. 5a. A diagrammatic representation of the section at Hoxne, Suffolk, drawn by Clement Reid and Reid Moir.



Interpretation by West	
DEPOSIT	CLIMATE
Non-calcareous clayey Sand and Gravel	Glacial
Calcareous Gravel	Periglacial
Silt and brecciated derived Clay-mud	Periglacial
Detritus Mud	Temperate
Brown Clay-mud	Temperate
Grey Clay-mud	Late-glacial
Boulder Clay	Glacial

Fig. 5b. The same section as drawn by R. G. West.

These two drawings show the succession of glacial and temperate deposits at Hoxne. Fig. 5a was drawn before the whole section was available for inspection, whereas Fig. 5b was drawn after the excavators had uncovered the full transect. Comparison shows the danger of attempting interpretation upon incomplete evidence.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

they too have suggested lines of communication and sites for settlement.

During the period when the Pleistocene ice-sheets and glaciers of Europe were actively eroding the surfaces over which they moved, intermittent and seasonal melting gave rise to the release and spilling out of enormous volumes of finely ground material—'rock-flour', sands, and gravels which spread in delta-like fans away from the ice's edge. At the same time a wide belt of country immediately to the south was too cold to support many forms of life and probably resembled tundra.

With the return of each spell of intense cold each individual grain of sand was subjected to further frost-splitting, until a diameter between 0·1 and 0·01 mm. was reached (when inherent elasticity of the materials seems to impose a limit).

In the dry cold condition which existed at the ice-sheet's edge there was thus an almost unfailing source of supply of material which could be moved by the wind (see Chapter 3). Over the ice-fields lay an anti-cyclone from whose centre violent winds constantly radiated—and as they passed over the ice's edge, they picked up the dust and eventually deposited it as loess.

In Britain and along the western shores of Europe where the climate is damp and 'Atlantic' little loess remains *in situ* though it seems probable that many of the loams and brickearths in river valleys contain redeposited loess as a major constituent. Eastward, however, the climate became increasingly 'Continental' and the loess covering increased in extent and thickness.

Loess forms a light and well-drained deposit and was thus the first choice of Europe's earliest farmers. It was along the loess belts that the knowledge of agriculture spread from the Near East where it originated.

Just as expanding ice removes fragments from an exposed cliff, so do growing ice crystals disturb level ground.

Evidence of repeated deep freezing and thawing is sometimes to be seen in ancient river gravels abandoned by the depositing stream: flat water-worn pebbles are all positioned with their long axes vertically instead of horizontally as they normally fall into position in water. With intensely cold air at the surface of the gravel, ice crystals, drawing upon moisture below, grow vertically and tend to tip up one end of each pebble more than the other. Then when the ice crystals melt, the stones, because of the movement of sand and silt amongst them, are unable to resume their first position. Repetition of the process ranges all the pebbles vertically.

On a smaller scale frost action can be seen to loosen pavements and floors as well as to disintegrate walls and the sides of ditches.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

In areas subjected to intense cold the entire surface of the ground, besides being shattered by frost, may be subjected through the growth of ice internally to what has been termed *frost heave*. A conjunction of solifluxion and crystal formation will produce a mixture and churning of the surface layers, so that pocketing and festooning may be seen where the deposits have been eroded into cliffs or artificially exposed—though these disturbances are not to be confused with those caused by the passage of glacial ice above the contorted layers.

Alternation of freezing and thawing may also result in a rough sorting of the upper ground into fragments of different sizes—the bigger stones moving outwards so that, seen from above, the surface eventually presents a pattern of stone rings. In sections the phenomenon is seen as pockets of fine-grade material separated by vertical columns of coarser.

Finally, let us turn to the effect of frost on cave deposits. In most circumstances the interior of a cave is one of the places best protected from the elements and external influences, but during a glacial phase, when great areas beyond the actual spread of ice-sheets are subjected to intense cold, freezing may be sufficiently deep and severe to effect the interior of a cave. The transformation of water contained in the walls and roof into ice then breaks off rock fragments of all sizes and these fall to the floor of the cave, sometimes to form an appreciable stratum over pre-existing deposits. The Upper Palaeolithic site of La Ferrassie, amongst many others, provided an instance of such a layer covering other deposits which contained Aurignacian implements.[1]

Where the cave is not very far below ground level and freezing has penetrated to some depth the floors of the cave may also be severely disturbed. Kent's Cavern in South Devon is formed only a few feet below the surface by percolating moisture in a limestone which overlies an impervious stratum of shale, so that there has always been a copious supply of water. At times, as often occurs also elsewhere, there have been actual streams running in the cave.

The advent of extreme cold, which penetrated from the surface, meant the formation of ice crystals within the moist deposits of cave earth and stalagmite upon the cave's floor. These crystals were able to draw upon water lower down to increase their size and as they did so immense expansion forces broke up the floor deposits. Frost-heave smashed stalagmites many feet in thickness and tilted the broken pieces at all angles.[2] No certainty can therefore exist concerning the stratum which originally contained the pre-glacial Acheulean hand-axes found

[1] D. Peyrony, *Préhistoire*, Tome III, pp. 1–92, 1934.

[2] E. Pyddoke. Final report on Kent's Cavern, Torquay, to the British Association for the Advancement of Science, 1954.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

in the cave, whilst the broken nature of the floor, combined with the now continuing activity of percolating trickles of water, makes the original position and sequence of even the later prehistoric material from the cave a matter of conjecture.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

6

Lakes and Ponds

IT IS THE nature of ponds and small lakes to be but ephemeral features of the landscape, for either overflowing water will eventually remove the dam which is barring the water's passage to a lower level or the depression in which the water is ponded will become completely filled with stones and silt carried in by the streams which fill it and with other accumulations.

In the latter case, the silted accumulations are likely to remain waterlogged and so to preserve non-calcareous organic remains. Incidentally, it is now thought that the large number of stakes found protruding from the mud at the sites of the Swiss Neolithic 'lake-villages', were originally driven into damp ground at the lake's side and not into the bed of the lake itself. Those parts of the stakes which were above ground decayed: those which remained waterlogged were preserved and it was only when the level of the water was lowered that the ground shrank and left part of the preserved stumps protruding.

The in-filling of a lake results from the erosive power of the water which feeds it. The flowing water brings with it whatever materials its speed and energy enable it to carry, but immediately the stream enters standing water its speed slackens and part of its load is shed. Thus delta-fans composed of the coarser part of the stream's load are built up at the point where the stream enters.

The surface of a delta is more or less horizontal and at its growing edge there is a steep drop into deep water. New material is added to the sloping surface as the stream tips it over the growing edge and such strata as exist in a delta-fan are thus not deposited one vertically upon another but at a steep angle, each one further than the last from the stream's point of entry into the lake.

Finer materials, the sand (0·06 mm.–2·00 mm.) the silt (0·002 mm.–0·06 mm.) and the clay (below 0·002 mm.), are carried further into the lake than coarser and are slower to settle, only the finest mud reaching the centre.

The volume and energy of the entering stream, however, will vary according to the season of the year: winter torrents will carry material of, for example, the sand grade further out into the lake than will be the case with the less powerful streams in summer. Sand will fall

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

comparatively rapidly to the bottom but the accompanying silt and clay grades of material will settle much more slowly: this sorting results in layers on the lake floor with coarser material at the bottom and the finer above: this process of sorting is repeated whenever new sediments enter the lake and new coarse material is deposited on the finer matter which has already found its way to the bottom. Successive layers in lakes fed by glacial melt-waters have been called 'varves' and attempts have been made, notably by de Geer in Sweden, where glacial melt-waters accentuated the annual in-rush of coarse material, to provide archaeological datings from them.[1]

It will be seen that, however slowly, the floors of all lakes are normally in process of being covered by successive layers of silt. Now as the 'rain' of fine matter is slowly falling through the water of the lake another 'rain' is falling upon the lake's surface—a rain of pollen from wind fertilized plants. The pollen and the silt finally settle together on the floor of the lake and are covered by later films. In this way a natural record is made of the history of the vegetation growing round the lakes shores and several analyses have been made of samples of lake floor silts. As an example, a succession of pollen grains preserved in silts from the English Lake District have shown a decrease in pollens from wild plants and an increase in pollens of cultivated cereals—and thus indicated the existence of agriculture—at a time much earlier than had been expected from other existing evidence. Several other changes in the local vegetation have also been reflected (see Chapter 10).

A most interesting archaeological sequence was provided by Dr Leakey's discoveries in the prehistoric lake deposits at what is now Olduvai Gorge in Kenya.[2] A complete succession of stone implements, in eleven stages, from Olduvan pebble tools to well developed Acheulean implements, was found, the different stages all in deposits stratified one above another. At this site early man was living on the shores of a Middle Pleistocene lake in a depression which was part of the Rift Valley complex. The basal deposits are lava and on these lie well-stratified tuffs (volcanic ash—not to be confused with tufa). Above these again are loamy lake sediments and intercalated with them is a deposit (Bed III) which may be of terrestial or lake origin (the experts disagree!).

Subsequent to the deposition of Bed IV, the last of the lake deposits, earth movements resulted in the draining of the lake and initiated erosion of the present gorge.

[1] See F. E. Zeuner, *Dating the Past*, pp. 20–45, Methuen, 1958 edition.
[2] L. S. B. Leakey: *Olduvai Gorge—A Report on the Evolution of the Hand-Axe Culture in Beds I–IV*, Cambridge University Press, 1951.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

The controversial Bed III contains boulders of lava and material which could be deposited relatively quickly on a dry surface by wind, by surface-wash, or by streams, but the presence in the bed of the remains of hippopotamus and crocodile make it appear likely that the rocks and soil were deposited in water.

Another African lake of great archaeological interest is that which lies in the Egyptian Fayum depression now some 147 feet below sea-level.[1] In Middle Pleistocene times the whole depression—possibly originally eroded by wind—was filled with a great lake, some 270 feet above the modern water-level, which has gradually shrunk to its present size. The lake was not entirely dependent on either rainfall or contacts with the River Nile but also tapped the great Libyan underground water-table, springs from which probably contributed to the lake even in very dry periods. The shrinking was intermittent and, at such times as the level of the water was sufficiently long maintained, waves and rainwash were able to build up shore-line sands and gravels around the lake's margin. A Middle Pleistocene date was confirmed archaeologically. Sub-aerially eroded remnants of these ancient and deserted shores may now be seen resting on the flanks of the depression many metres above the level of the present lake: they show as flint gravels eroded into spurs. The highest lake could not have been in existence in Neolithic times since a series of occupation sites of that period lie along an abandoned shore-line at a level thirty feet or more below the high level shore-line.

Some idea of the kind of conclusions to be reached as a result of the study of lake deposits can be obtained from the Fayum report. The writers state that the earliest deposits in the Pleistocene lake '. . . appear to have been white diatomaceous clays' (see page 96) 'which occupy the floors of nearly all the depressions and . . . run right up to and under the sands and clays of the cliffs and stacks . . .' —that is, the eroded remnants of later lake floor deposits. 'At the time of their formation very little run off can have entered the lake on the northern side. Had it done so the clays must inevitably have been mixed with sand and other coarse detritus: their purity leads to the conclusion that the climate when first the lake was formed was probably a fairly dry one. Later the predominance of sands and clays . . . indicates an increase of rainfall.' More material was being washed off the ground's surface and into the lake.

During the Neolithic period the lake shrank by forty feet in vertical depth but was maintained at 140 feet above the present lake level for a long period during which intake and evaporation seem to have been

[1] G. Caton-Thompson and E. W. Gardner, *The Desert Fayum*, Royal Anthropological Institute, 1934.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

counterbalanced. This made possible a remarkable flourishing of agriculture around the lake's shores, where abandoned silts were cultivated with hoes.

More will be said about shore-lines and about the parts played by fauna and flora in the stratification of lake floors in following chapters, but two archaeological points may be brought out here.

First, not quite so obviously in the field as in theory, where there has been a receding water-level the oldest waterside human settlement will be found highest up the banks of the depression which once contained the lake.

Secondly, as materials are carried by trickles and streams off the land surface and into the lake, filling of the hollow will begin at the margins of the water, mud or sand-flats are formed round the lake. These flats extend almost exactly at water-level away from the shore and, as in the case of delta fans, they then plunge steeply: stratification thus proceeds more horizontally than vertically and artefacts of very different date dropped over successive edges of the advancing mud-flat or delta-fan may be found at the same horizontal level.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

7

The Sea

MENTION HAS BEEN made in the foregoing chapters of changes in the level of the sea; but before any further reference is made to them, the part played by the sea in erosion of the land and the formation of strata must first be considered.

Foremost and most evident is the erosive work of waves. Formed by the uneven pressure of wind on the sea's surface these undulations may travel for thousands of miles but with little resultant movement of the main body of the water. It is only when the waves reach the shallow water of a shelving coastline that they lift themselves into crests and plunge forward as 'breakers'.

Lashed by a gale these breakers may hurl forward many tons of water with each wave. Crashing on to the cliffs and shores of the sea coast, the waves are then able rapidly to erode the land. Cliffs are undermined and falls result. Large and small fragments of rock are then rolled back and forth by the sea at each tide, the more durable stones, battered and rounded, becoming *shingle*. Further wave action adds more fallen rock and eventually reduces the smaller fragments to the size of sand. These are the principal elements in a sea beach: in relatively calm weather they provide the cliffs with protection from the slapping and hammering of the waves, but at times of storm they are themselves lifted by the waves and thrown, with the water, at the cliff-face, so assisting in its destruction.

Marine erosion takes place principally between the levels of high and low tide so that, as the cliffs recede, an almost level platform of unattacked rock is left. Such a marine planation platform may extend for a considerable distance out to sea, particularly in areas where cliffs are soft and easily cut back by wave action.

It is upon such platforms that any accumulations of gravel and beach material must lie, the thickness of the deposits above the platform depending upon a variety of local factors, e.g. the violence of storms, sea currents, and the height above mean sea-level of the maximum local tides, but, where they are being formed today, the eroded platforms themselves will be found at approximately the same level throughout the world.

Partly as a result of the prevailing wind, which to some extent

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

decides the angle at which waves shall strike the coast, and partly as a result of the off-shore currents in the sea (details of whose origin need not concern us here, but which arise principally from inequalities in temperature) there is a tendency for sand and shingle comprising a beach gradually to drift along the shore in a fixed direction. That variability in the power to transport which depends upon the energy of moving water once again results in a sorting of materials, and as the beach materials are set down further along the coast they will tend to be deposited as banks of coarse shingle, fine shingle, and sand. Finer grades of material may be completely removed—perhaps to be deposited far out to sea.

The long-shore drift will sooner or later carry beach materials to a point on the coast where a river is entering the sea and, unless the stream is sufficiently powerful constantly to remove it, the beach will gradually extend across the river's mouth, forcing it to debouch further and further along the coast. In this way a bar may be built right across a river's estuary—and within the bar the partly dammed river, its speed reduced, will deposit its alluvium. It will start to fill its estuary with wide level meadows, confining itself to a channel no broader than its bed upstream.

Seaford, in Sussex, facing the end of just such a bar, was once a port for shipping. Continual extension of the bar, however, tended to dam the river's outlet until flooding resulted in a breaching of the bar at the other side of the old estuary—i.e. at the point where the river naturally flowed before the bar's formation. By 1565 a 'Newe haven' had been established: finally, according to tradition, the Great Storm of 1579 resulted in a complete break-through of the river to the sea. Seaford's history as a sea-port was ended, Newhaven's begun—but, it should be added, Newhaven's position today is secured only by the building of a great mole-wall to hold back the drifting shingle and by constant mechanical dredging of the river-channel.

Dungeness in Kent, some miles further along the same coast in the same direction as the shingle drift, provides an example of a different action of the sea. Here, where the long-shore current turns away from the land, instead of eroding the coast and transporting sand and shingle the sea is depositing its shingle load so that a great bank of it, now several miles in width, is extending itself seawards at a rate of some 6 to 10 feet a year.

Except for slight ridges, which resulted from the throwing up of shingle to different heights by storms of different violence, the whole surface of the great shingle bank is uniformly level, new deposits being added laterally, so that, for instance, glass-bottles left at half-tide by picnic parties in 1750 and 1950 will be found buried in the same vertical

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

depth of shingle, though the earlier ones will be further from the water's edge.

In spite of the tendency of waves to throw material on to the shore sea currents and vigorous rivers carry a great deal of material out to sea and the existence of extensive offshore mud- and sand-banks round the coasts is well known as a source of danger to sailors. These deposits are constantly being re-sorted, supplemented, and removed, but in the deep oceans to whose depths the effects of surface storms and currents never penetrate little wave or river eroded matter ever penetrates.

Here perhaps some very small proportion of the very finest clay grade sediments may find its way but in general, apart from air-borne dust, the floors of the great depths receive as deposits almost exclusively a constant 'rain' of organic remains. Under very great pressure calcium carbonate becomes soluble and so not all calcareous skeletons survive to accumulate, but siliceous skeletons, as of Radiolaria and Diatoms, are not so affected and form many of the deep oozes. Lying thus throughout many millennia undisturbed by storms or changes in sea-level the deposits can provide an unbroken record of changes in the character of the 'rain'. Sample cores from borings into the sea bed at such depths have provided useful confirmation of conclusions concerning changes in climate which have been reached as a result of different studies: the succession of strata exposed in these cores from deep sea deposits shows how the organic population of the sea has changed between cold-tolerant to warmth-loving forms.

Something must now be said about changes in sea-level: those which concern the archaeologist are principally only those which have taken place during the last million years or so—the period during which man in more or less his present form is known to have existed.

Space does not allow of a detailed dissertation on or reference to geological researches into the question and the reader must therefore accept that there has been a continuing and world-wide general falling of the average level of the sea over the whole of the period with which we are concerned—a fall which has been going on since at least the time when the sea was 100 metres *above* its present level.[1] The cause is not properly known but appears to be connected with a sinking of the floors of the major oceans.

A cause of major fluctuations in this general slow falling of sea-level has been the failure of evaporated water to return to the sea, as a result of its being locked-up in the form of vast ice-sheets and snow-caps during glacial phases of the Pleistocene Ice Age. It has been estimated that the polar caps retained so much of the water evaporated from the

[1] F. E. Zeuner, *The Pleistocene Period*, Ray Society, 1945.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

sea that sea-level fell during major glacial phases to maybe 300 metres *below* the present level.

These changes in level—referred to as eustatic—were imposed upon the general continuing fall so that when, in interglacial periods, the ice-caps melted and water did return to the sea, although the sea-level rose again it never quite attained its former high level. In this way the earlier sea-beaches and estuarine river deposits were not engulfed and destroyed, but left round the world's coasts and estuaries high above the later and present shore-lines.

The existence around the world's coasts of substantial marine beach deposits at or near the same recognizable levels (e.g. 100′, 50′ and 25′) is attributable to the fact that during certain interglacial phases the sea remained substantially at the same level for periods sufficiently long to allow of the wave-cutting of marine platforms and for the accumulation of sands and gravels thereon. These ancient shore deposits are not to be confused with the raised beaches mentioned below. Relics of beaches and erosional platforms which are found at the same vertical height above the present sea (in those places which have not been elevated or depressed by earth movements) can then be considered as roughly contemporary—as can human artefacts found within them.

Some work has been done on checking the contemporaneity of beach deposits by a study of the included remains of molluscs. These may differ from those of the present day, and Godwen Austen has described the fauna belonging to the warm episode represented in the sequence at Selsey Bill as similar to that which would now be found twelve degrees further south.

Deposits attributable to an ancient shore-line are to be seen at Slindon near the south coast of England, where beach shingle and sand occur at some 135 feet above the present sea, and here have been found flint hand-axes of Middle Acheulean types.[1] The implements are sharp and unrolled. At 80 to 90 feet above present sea-level on the same slope of the chalk hills, as they dip towards the sea, is another series of beach remnants which also contain implements. These implements are battered and rolled and might at first appear on that account to be older than the sharp tools in the higher beach. In fact the sea must have begun to retreat immediately the implements had been laid upon the upper beach and before it had time to roll and batter them.

Had the sea advanced from the lower to the higher levels its waves and currents would have destroyed the lower beach completely. Thus the inclusion of implements in the lower beach must have taken place more recently than in the upper beach. The beach material itself was

[1] E. Pyddoke, London University Institute of Archaeology, *Annual Report*, No. 6, 1950.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

in this case probably deposited during a 'retreat stage', viz. a period when the recession of the sea was temporarily halted.

A third main cause of change in the relative levels of sea and land is an upward or downward warping of the land surface as a result of deep-seated earth movements. In such cases the movements—called tectonic—are localized instead of being traceable throughout most of the globe: it is the land-level which has altered, not the sea-level.

One finds an instance in the estuary of the Thames and in East Anglia. North of the river the land, and with it implement-bearing gravels, has sunk since the period of the Great Interglacial when the sea stood at about 100 feet above its present level.

Estuarine gravels and sea beaches deposited at this time are to be found at their original level along the southern coasts of England and along the south bank of the estuary of the Thames (e.g. at Swanscombe in Kent). The land north of the river, however, has been subjected to sinking so that equivalent deposits at Clacton in Essex lie near to present sea-level and even below sea-level further round the East Anglian coast.

It is obvious then that equivalence of age, both of such gravels and of their contained implements, can only be assumed, from their absolute heights above present sea-level, when no tectonic movements have taken place.

Continuance of the same land sinkage in East Anglia was probably in part responsible for the marine transgressions which resulted in deposition of the marine clays and silts which lie below peat in the Cambridgeshire fens (see Chapter 10). It was the same sinking which resulted in the well-known Cromer Forest Bed of the Norfolk coast being now partially covered by the sea: at the time of its growth it must have been at least 200 feet above the present sea-level.

Of a different character is the swamping of the post-glacial forests: the sea continued to rise as a result of ice melting for long after the end of the last glacial maximum and covered extensive areas around the coasts of Britain and elsewhere where trees were growing in Neolithic times, say 3000 years B.C. Although some implements and animal remains have been found amongst the tree-stumps of these 'submerged forests' much of archaeological interest is probably now buried under sand and mud even if it is not covered by several feet of salt water. Particularly affected would be coastal and estuarine settlements of any preceding Mesolithic 'strand-loopers'.

In 1931 part of a fishing leister-prong typical of the Mesolithic 'Maglemosans' who lived by stream and mere was brought up by chance in a fishing trawl-net from the Leman and Ower banks twenty-five miles off the Norfolk coast: it was embedded in peat from a land-surface once accessible to man.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

Yet another kind of movement complicates the comparison of the heights above sea-level of different coastal sites: lands which were covered by the great ice-sheets of the glacial epoch were depressed by the sheer weight of ice, large areas of the Earth's surface sinking vertically.

With the removal of this weight upon the thawing of the ice, the depressed land began to resume its former shape: recovery was slow and indeed is still continuing. Re-elevation of this kind, called isostatic, is greatest at the centre of the area once depressed and thus beach deposits laid down on shore-lines which run at right angles to the contours of the risen dome rise by amounts which differ according to their distance from the dome's centre (see Plate VIII). These are true 'raised beaches'[1] and they must not be correlated, merely on account of level above the present sea, with strata in stable areas: there is, for instance, no equivalence of dates between the Levalloisian implements found in gravels at 25 feet above sea-level near the mouth of the Thames, which date from the interglacial period before the Last Glaciation of Britain, and Obanian implements from sea-cave deposits at a similar height in Scotland which are post-glacial.[2] Nor can there be any correlation with artefacts in strands and caves in Sweden, which has also been re-elevated, but at a different rate, since the removal of the ice.

Before turning, in the next chapter, from the sea to rivers and estuaries, which it profoundly affects, two effects of the sea upon stratification should be noted, it being remembered that, as throughout all studies of stratification, any one agent may have more than one effect and may be at work at the same time as others.

First, then, it is of interest that the sea can affect and change vegetation growing at a considerable distance from its shore—for wind-carried salt spray can kill plants and open the way for the wind to erode the soil and to form sand-dunes. At the same time there is some tendency to flocculation and the creation of crumb-structure in clay soils as a result of salt: they are thus rendered even more easily movable and attacked by sub-aerial erosion.

Secondly, there is the question of interdigitation of strata.

Waves beating at the foot of a cliff will hollow out notches and caves. It sometimes occurs that these survive as evidence of a former high sea-level, as happens for instance at the Grotte du Prince at Mentone on the Mediterranean. Here sea-beach deposits were found below a cone of debris, amongst which were Upper Palaeolithic levels: the beach provided a *terminus post quem*. Incidentally, in the cave walls now high above the sea are holes bored by marine molluscs.

[1] See W. B. Wright, *The Quaternary Ice Age*, Macmillan, 2nd ed., 1937.
[2] *Ibid.*

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

More usually the sea's undermining results in a cliff-fall. If the rock fragments are not rapidly removed they may become covered by fresh beach material brought by the waves from further afield. There may thus be an alternation of different but almost contemporary layers.

A good example of interdigitation of this kind is to be seen at the Black Rock at Brighton where the modern sea has cut a section at right angles through the ancient beach 25 feet above its present level. Above the beach and cliff-fall deposits lie many feet of solifluxion deposits (see page 45). The junction between deposits is not everywhere entirely clear, and as a result of cliff-fall material being mistaken for solifluxion material the latter has sometimes been erroneously interpreted as being contemporary with high sea-levels: however, conditions of cold sufficient to result in large scale solifluxion probably only obtained during glacial phases when the sea was at a very *low* level.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

8

Rivers and Streams

THE COURSES OF most rivers which do not fall steeply into the sea are divisible into two parts: in the upper and steeper reaches the stream is actively cutting a channel into the rocks over which it flows, whilst in its lower reaches eroded material is being deposited; but it should be noted *en passant* that the character—and even the direction of flow—of a river may change. During glaciation many rivers in northern Europe were blocked by ice and diverted: in some cases, instead of being permanent streams supplied by rainfall, they became merely channels of escape for glacial melt-waters. It was in this way that fragments of rocks which occur only outside the present catchment area were introduced into the gravels of the River Thames.

The erosive power of a sudden torrent across a land-surface has been noted above: of rivers Charles Lyell wrote,[1] '. . . when we are speculating on the excavating force which a river may have exerted in any particular valley, the most important question, is not the volume of the existing stream, nor the present levels of its channel, nor even the nature of the rocks, but the probability of a succession of floods at some period since the time when the valley may have been first elevated above the sea.'

Reference to this 'elevation' above sea-level was made in the last chapter. Its effects on the lower reaches of rivers will be mentioned below. Concerning the upper reaches of rivers we need here only note that there largely is the source of materials for the building of strata downstream.

Something of the extent of river erosion and deposition may perhaps be inferred from the fact that the River Po in Italy, which carries much of the melt-water from the Alpine snows, is extending its main delta into the Adriatic by some 46 metres each year: it has been estimated that the amount of solid material carried in suspension amounts annually to some twelve million cubic metres, and the growth of the delta might be even more each year were it not for the fact that the main mouth is now exposed to the action of a marine current which hinders deposition of sediment.

As soon as a river's bed begins to level out and the water's speed

[1] *Principles of Geology*, 1830–3.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

and power are reduced its load is dropped and deposited as gravel-beds, sand-banks, and mud-flats—ideally in that order, though eddies and currents usually result in rapid changes in water-speed so that sand and gravel grades are deposited together. The river then develops its 'flood plain', a wide flat base to its valley, across which it normally wanders peacefully towards the sea. In seasons of spate the flood-plain is inundated and silt is spread over a comparatively level floor. Ancient river-silt deposits sometimes survive as 'brickearths'. The water-laid deposits are not composed entirely of even level spreads, for, especially in the estuarine area, mud and sand are piled into low banks by tides, winds, and currents and the surfaces are broken by drainage trickles, animal wallows, etc. 'Tidal scour', the result of the filling and emptying of the tidal reaches twice a day, also helps to clear away some part of what might have been deposited.

Of Mohenjo-daro in the valley of the Indus, Sir Mortimer Wheeler writes:[1] 'One of our tasks was . . . to penetrate below the present water-table towards the foundations of the city far below it. For forty centuries or more, since (and before) man first built there, the swollen waters of the Indus, in the spring season when the snows melt in the high hills, had flooded the surrounding plain and left upon it fresh layers of fertile alluvium. Century by century, the land-surface had risen and, with it, the water-level below that surface. The earlier strata of Mohenjo-daro thus lie engulfed beneath many feet of water and mud. . . .'

Such may be the happenings of a brief four thousand years in the history of one particular site on one particular river. The story however needs to be pursued backwards into time: the River Thames will provide an adequate example.

Some 250,000 years ago (there is no need here to go further back in prehistory) the river was flowing across a flood-plain some 100 feet above the level of the modern river. Its tributaries and headwaters, supplemented by all manner of washings from the surrounding land-surface, were bringing into the river materials of different origins. It rolled along its floor Clactonian implements, bones and pebbles, and as they rolled they became battered and rounded. As is the case with all streams the river followed a meandering serpentine course through its flood-plain meadows: in times of spate the river flowed fast, cutting and undercutting its bank on the outer sides of each curve, either removing materials from the valley side or bearing away gravels which it had formerly deposited at the point. The eroded material was carried downstream till it reached the bank on the inside curve of a bend in the river: on this inside of the curve the river flowed more slowly

[1] R. E. M. Wheeler, *Still Digging*, Michael Joseph, 1955.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

(for water on the side nearest to the geometric centre of the curve has to travel a shorter distance than that on the outside) and the load was deposited as a sand or gravel bank.

The process was repeated, more and more gravel being built upon the inside curves, whilst at the same time some material was being removed from the outsides. So the river continued to meander back and forth across its flood-plain, and to its banks came Acheulean man and his contemporaries, the straight-tusked elephant, Merk's rhinoceros, the hippopotamus, the deer, and the bison: Acheulean hand-axes and bones were swept into the river and became one with the river gravel. The hand-axes at Swanscombe are often sharp and show no signs of battering and rolling in the stream. It can therefore be assumed that they have travelled only a short distance, if at all, and that the makers left the implements almost exactly in the place in which they are found. On the other hand the rolled Clactonian implements may have been swept to their resting place from many miles away—perhaps even collected and carried by surface-water from a land-surface now completely eroded away.

After the formation of the flood-plain, on which walked Acheulean man, the level of the sea fell (see page 60) and the river was 're-juvenated' in what are now its lower reaches, that is, it became once again a river which was cutting down its bed towards sea-level instead of one whose estuary was being choked with gravels, sands, and muds. The water's speed and carrying power were increased and by far the greater part of the flood-plain deposits were washed out to sea.

The history of the River Thames is long and complex.[1] It is sufficient here to say that patches of gravel, remnants of the erstwhile flood-plain, are still to be found some 100 feet above the present river. Such a patch is to be found at Swanscombe in north Kent.[2] Commercial excavation of the gravels, at Barnfield Pit there, exposed a world-famous section.

The bed of the river—the 'bench' on which the gravels lie—was cut by the stream down to 75 feet O.D. and upon this lies a coarse gravel which includes the rolled Early Clactonian flakes and cores. Towards the top, this deposit becomes finer in grade and suggests that the flow of water over the spot was not so rapid as at first. Above this gravel is a loam containing mollusc shells and penetrated by root holes which show that flowing water almost abandoned the spot and left only a mud-flat in which grew marsh plants and reeds. The sequence

[1] See W. B. R. King and K. P. Oakley, 'The Pleistocene Succession in the Lower Parts of the Thames Valley', *Proceedings of the Prehistoric Society*, II (new series), 1936.

[2] Report on the Swanscombe Skull, prepared by the Swanscombe Committee of the Royal Anthropological Institute, *Journal of the Royal Anthropological Institute*, LXVIII, January–June, 1938.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

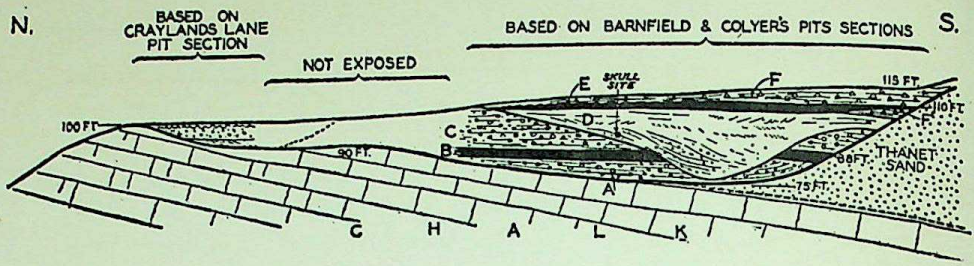


Fig. 6. A diagrammatic section through the gravel deposits at Swanscombe, Kent. A bench (A) has been cut into chalk and Thanet Sand, and the channel filled with river gravels, sands, and loams (B and C). At a later stage a new channel has been cut into the gravels and then choked with a second series of stream-borne alluvium (D and E). Last the site has been covered by a spread of solifluxion material (F).

is normal to the course of any river meandering over a flat valley floor: initially the stream is strong enough to carry gravel to a given spot and to wash finer material away, but as its power is reduced it can carry only sand and finally only fine silt. Eventually, when the river had meandered to a course perhaps a mile or two away from Swanscombe, the site became comparatively dry and the loam's surface was weathered by sun and rain.

The river, however, returned to the spot, and a branch of it, if not the main stream, cut a new channel (see Figure 6) into the 'lower gravel' and later refilled it with another gravel—the so-called 'middle gravel'—which continued to be deposited and spread above the existing loam. It is this middle gravel which has become well known on account of the finding in it of thousands of Acheulean hand-axes, animal bones, and parts of the skull of Acheulean man (or more probably woman!).

The succession is repeated, for above the second sequence of layers of sandy gravel, which bear witness to their having been bedded into position by a flowing stream, is once again a loam. The loam's lower levels contain shallow-water shells but this loam too became dry, when the river wandered away and began to cut down its bed below the abandoned gravels, and its upper part is devoid of shells and other calcareous matters, which have all been leached away by percolating rain-water. The section is completed by a gravel of a different origin, a solifluxion deposit.

Once a river has sufficiently adjusted its vertical position to the level of the sea or lake into which it flows, it will not require to cut the lower and middle reaches of its channels any lower. As the stream meanders and forms new channels by lateral cutting, the rock floor of the valley will always be eroded to the same level. On the resulting

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

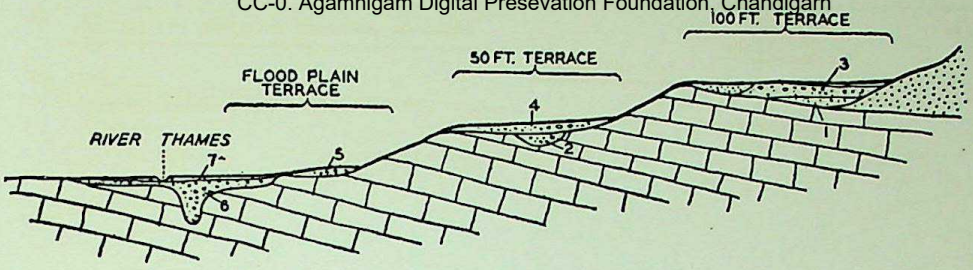


Fig. 7. This diagram shows the principal ancient flood-plain remnants as they appear in terraces on the south bank of the River Thames in north Kent. Cut into the chalk at a time of low sea-level is a channel (6) much below the bed of the present river. It is filled with fluviatile deposits and has become a 'buried channel'.

flat 'bench' of rock lies the river's alluvium—its gravels, sands, and silts—and so long as the sea- or lake-level remains constant this alluvium will continue to be sorted, re-sorted, and redeposited by the stream. Gravels lying at the same bench-level are therefore only contemporary in the wide, geological sense.

As the river meanders it deposits alluvium to the same depth—approximately the same as the depth of the water—all over the flat floor of its containing valley. If the sea—the base-level—rises, a greater depth of alluvium will eventually be deposited and former river channels will be choked, recording themselves occasionally by differences between bank and infilling materials as 'buried channels'.

On the other hand, when the sea falls the river begins to cut down its bed and to adjust itself to the new base-level. Alluvium on the floor of the existing valley begins to be eroded and eventually only patches of the old alluvium rest on the flanks of the valley while the river makes for itself a new flood-plain maybe many metres below its former course.

The process may then be repeated so that gravel remnants survive at many different levels (see Figures 7 and 8) and may have the appearance of steps on the valley's flanks: such stepped remnant deposits are termed *river terraces*. The surfaces of these gravel patches after centuries and millennia of erosion will all be at different levels: it is therefore the levels of the benches on which the gravels rest which must be sought if an attempt is to be made to relate the gravels to each other and to the history of the river: only so can relative dates be given to implements and fossils found in the gravels.

Whenever the sea remained for long at one level wide marine platforms could be eroded: at the same time the river estuaries remained also comparatively stable and prolonged meandering resulted in wide valley

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

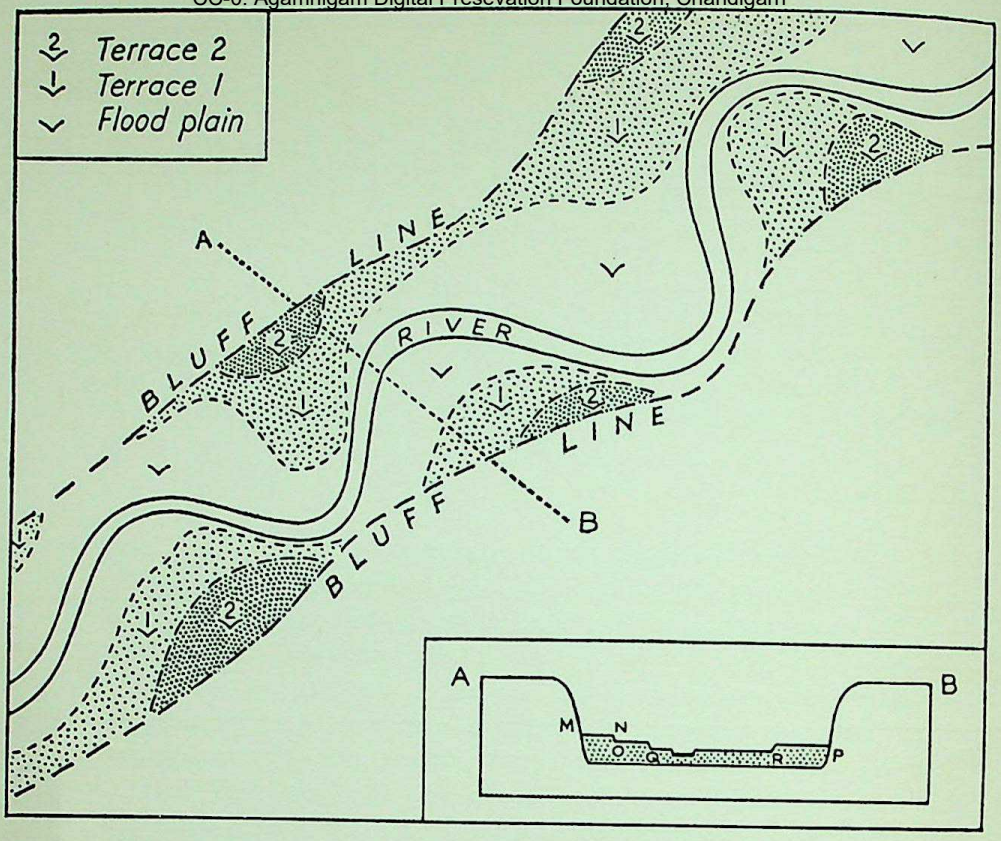


Fig. 8. Sketch map to illustrate the meandering course of a river between its valley walls and the formation of river terraces; terrace 2 is the older. See also the frontispiece.

floors. The valley deposits were in fact co-extensive with the sea-beaches.

A fall in sea-level resulted in down-cutting by the river which left remnants of its valley floor deposits on its flanks. Since the sea never regained its former level the river estuaries never regained theirs and the ancient gravels remained on 'terraces' which are recognizable at certain heights very much as are sea-beaches (Figures 9a and b).

It follows from the foregoing remarks that as full an understanding of a river's history as possible is necessary before the relative dating of Palaeolithic implements found in its gravels can be contemplated. The normal gravitational sequence with earlier deposits buried beneath later accumulations does not entirely apply—for the youngest deposits of an eroding river are at a lower level in relationship to sea-level than more ancient deposits; there is normal superposition when a rise in sea-level results in their being flooded and buried in estuarine silts (see Figure 10).

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

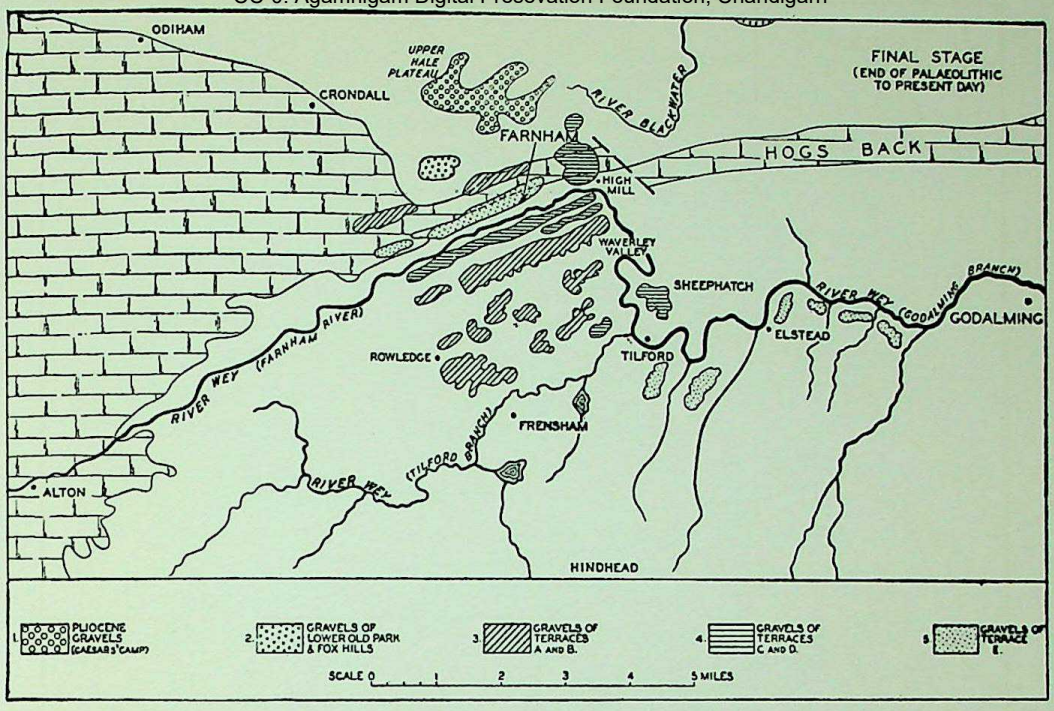


Fig. 9a. Sketch map of the Farnham, Surrey, district. The Farnham River, which once flowed into the valley of the River Blackwater, has been captured by the Godalming branch of the River Wey and now forms part of it. Remnants of river gravels surround the area.

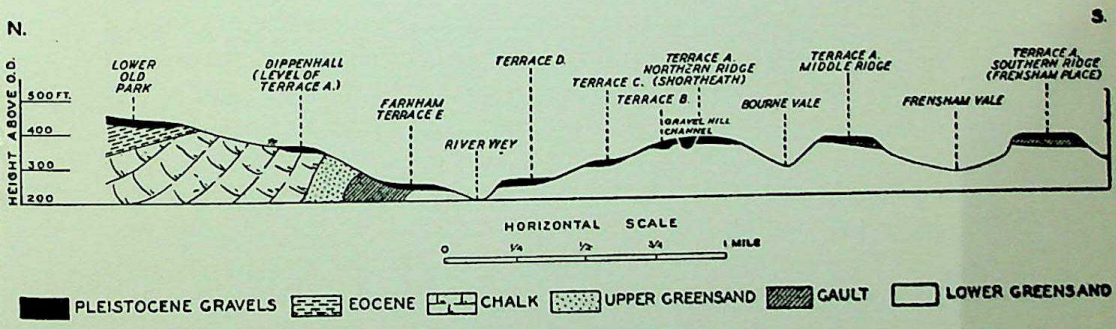


Fig. 9b. A diagrammatic section of the same area showing the relative positions of the gravel spreads.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

It should also be borne in mind that a current of water produces *false bedding*—fresh material is deposited by the current against the *side* of an established gravel, sand, or mud bank which has a maximum height very close to the surface level of the water. Successive deposits therefore tend to lie in layers which, being built up laterally, have the *appearance* of strata which have been deposited vertically one upon

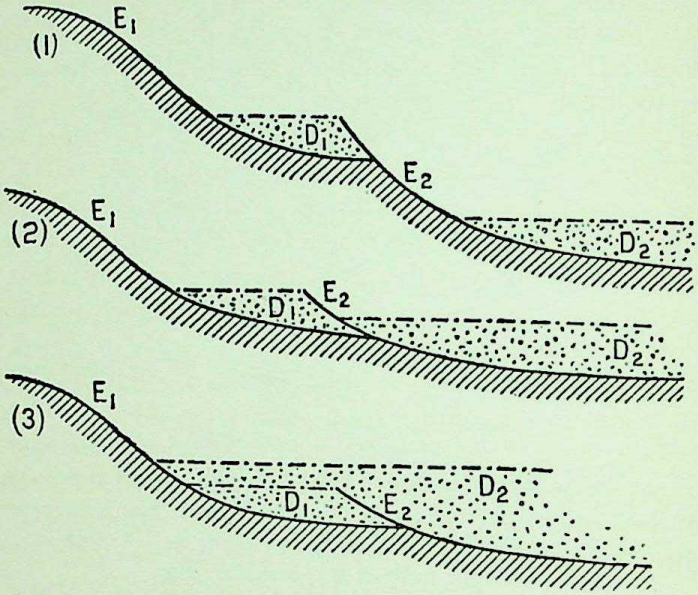


Fig. 10. Diagrams showing three possible relative positions of two layers of deposits, D_1 and D_2, following erosions E_1 and E_2.

another and then tilted so as to assume an angle of 45 degrees. In this case artefacts found at the same vertical level may in fact have been laid in position on a level with deposits of different dates.

Extensive exposures of river deposits and the benches on which they lie are therefore necessary and the dating of artefacts must depend on a geological dating of their matrix—never vice versa.

A study of river history may also lead to a proper understanding of the nature of much later sites. The Early Iron Age village at Glastonbury[1] for instance is now twelve miles from the sea in low-lying meadow-land: but the true nature of the site has been masked by silt which has now filled in the course of a stream which once flowed by the village and which has obscured the tongue of firm ground which led across marshes to connect the area with the Mendip Hills.

Extensions of estuarine silt have similarly now pushed back the

[1] C. F. C. Hawkes, 'The Lake Villages of Glastonbury and Meare', *Archaeological Journal*, CVII, 87–90, 1950.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

sea and left inland the Roman port at Richborough, once on the River Stour in Kent, whilst ancient settlements once on the coast are now many miles from the mouth of the River Tigris.

Deposition of sediment in a river's estuary is facilitated by the fact that fine matter in suspension in the river tends to flocculate on reaching salt water.

The sequence of faunal and floral remains within fluviatile deposits will appear to be different in different parts of the river's valley. With the advent of a glacial phase and a subsequent fall in sea-level a river cuts down deeply in its lower reaches. As an example, any deposits left on the new floor of the valley will include the remains of sub-arctic organisms. A return to warmer conditions in the following interglacial period will bring with it warmth-loving animals and plants: it will be the remains of these which become incorporated in gravels and sands deposited in the tidal reaches of the river when the sea returns, and they will cover and lie above the gravels containing the cold-loving forms.

Above the tidal limit there is an apparent reversal of the sequence for it is normal to find these 'cold' gravels overlying 'warm' gravels. The explanation is simple. Under conditions of extreme cold there is little regular flow of water in the river's valley so that remnants of 'warm' gravels from the preceding interglacial phase are left undisturbed. However, it is in those reaches of the valley which are highest above sea-level that frost is most destructive: great quantities of scree and loose material will be produced on the mountains and hillsides and any sudden thaw will result in its being swept by melt-water into the valley. There, with any contained cold-loving animal and plant forms, it will spread above the earlier 'warm' deposits.

Plotting, as a graph, the height of a present-day river at intervals against direct distance from the river's source produces a curve representing the generalized *profile* of the river's course: this is its *thalweg*.

Each fall in the sea-level results in a fall in the lower reaches of the river so that it has to cut down its bed. The point where the line of the new down-cut course meets the original thalweg curve is a *knick-point* and here the water rapidly flows over an angle in the profile. Slowly the knick-point is eroded and moves higher upstream.

Where more than one change in sea-level has affected the river there will be more than one knick-point.

Above knick-points there may be convenient fords whereas immediately below the increased speed of the stream as it descends at a steeper angle encourages the building of water-mills.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

9

Fauna

HAVING CONSIDERED, IN all too broad outlines, some of the inanimate agencies which give rise to stratification, let us now turn to the part played by animals.

The effect of the mere passage of animals over the ground is negligible, though the habit of some to follow repeatedly the same path may result in destruction of the vegetation and expose the earth below to erosion by surface-water. Many animals—even mice, and including men—wear paths through the vegetation carpet by constantly following the easiest path: such paths, by avoiding tussocks and rocks, closely correspond with the natural path of water, which soon cuts the path to a gully. Such is the origin of most of the 'hollow ways' on open chalk downs.

The breach of a dyke in Norfolk in the 1950s which caused extensive flooding was thought to have begun at a point where cattle came to scratch their flanks on an old post and where the trampling of their feet had loosened and lowered the top of the earthen bank. The layer of mud left by the flood may well one day be recognizable as a horizon in a section through the soil.

Compared with the oozes in the deep oceans, which may be composed—as is chalk—almost entirely of animal remains, deposits on the land's surface contain extremely little animal material in their composition. The bodies of animals which die on land are normally rapidly devoured and decomposed by feeders on carrion and by bacteria, whilst residual skeletons are mostly disintegrated by those same agencies—rain, wind and frost—which make soil from rock.

Only in protected places are animal remains likely to be preserved, and such protection almost always results from natural—or, where man is concerned, intentional—burial. Bones of a hippopotamus, with a concave-based arrow-head amongst the ribs, were found in the Fayum protruding through a floor of silt. 'Its burial in silt need not however, necessarily denote a lake deposition, since drainage from the scarp had redeposited much of the soil.' In fact, where bones are concerned,

[1] G. Caton-Thompson and E. W. Gardner, *The Desert Fayum*, Royal Anthropological Institute, 1934.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

most of the protective layers are deposited by water—the greater part actually in water.

Since a river has usually moved the gravel and its contents at least a short distance it is not normally possible to say how particular animal bones came to rest in its gravel-beds, but two principal ways can safely be assumed: either the animal's dead body—or parts of it—were washed off the land-surface and into the river (along with implements) by torrent or flood, or else animals were drowned in the river itself—either while trying to cross it or its marshy fringes or while drinking at some treacherous spot.

Mention should perhaps be made *en passant* of the frequent finds in New Zealand of the lower leg bones of the extinct emu-like moa: the birds seem to have sunk into and become trapped in soft mud and only the buried parts have survived. Not dissimilar was the fate of the sabre-toothed tigers in California which were trapped in pools of bitumen, and the rhinoceros which sank into a salty bog at Starunia in Galicia, Eastern Poland. The following extract may be sufficient to complete the picture:[1]

> 'These deep mires, or "pits" as they are termed in local parlance, constitute veritable death-traps, as far as the moorland cattle are concerned. They are particularly dangerous in the early spring when their treacherous depth is increased by long rainfall. The cattle also are in poor condition at this time of year, as the result of winter privations, upon which account the perilous lure of the bogs becomes all the more irresistible.
>
> 'Very few are drowned, or even suffocated. By far the greater number perish from the effects of exhaustion or chill, due largely to their weak state . . . The toll taken by the bogs is always heaviest in the lean months of March and April, when hunger induces the cattle to enter them. There is always the most grass in the wettest places, together with emerald-green mosses which tempt the beasts to venture farther than prudence might dictate and one false step is sufficient to land them in difficulties. It is nothing unusual to see the corpses of two or three bullocks or ponies in a pit no bigger than a tennis-court.
>
> 'To human beings the danger is not so great, as with the exercise of ordinary care one can usually keep out of serious difficulties . . . it often happens that deep and dangerous places are scaled over with a top crust, which will bear a man stepping with care, though cattle frequently break through . . .'

Dr L. S. B. Leakey writing[2] of Rusinga Island, Lake Victoria, Kenya,

[1] Douglas Gordon, *Dartmoor in all its Moods*, Murray, 1931.
[2] Letter to author, 20 September 1957.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

says: 'We also had a large pot hole, which must have become a temporary water hole, with the bones of animals and reptiles that had fallen in while trying to get at the water.'

A very full knowledge of the habits of the animals whose remains are found (or at least of those of their modern representatives) is necessary before their archaeological importance can be properly assessed. Here may be mentioned the remarkable 'pockets' of bones which have been found in fine-grained silts on Rusinga Island—one of the pockets 2 feet by 1 foot by 6 inches containing remains of four apes and a number of rodents. Otherwise the horizon was barren as far as mammalian remains were concerned. These concentrations have puzzled geologists but Dr L. S. B. Leakey has been able to draw attention to the fact that crocodiles were very common in the Rusinga Lake. He writes:[1] '. . . we know that crocodiles today have *larders* in the fine gravel mud off shore. If they have more food than they can eat they will drag an animal or part of it and bury it in the mud for another day. As a result of this, we incline to the view that these Miocene pockets of fossils *may be* examples of crocodiles' larders.'

If bones can be shown to be contemporary with the deposit in which they lie their ascription to a species whose habits and habitat are known will provide a useful indication of the climate and natural environment at the time of deposition. On the other hand, it is possible that they have been washed out of their original deposit and re-deposited in a later one—in which case, unless care is taken, the determination of climate can be falsified. A change in climate may be indicated by the occurrence in a deposit of the bones of animals with a cold habitat above or below those of warmth-loving forms.

Many Pleistocene river gravels contain within them the bones of contemporary animals and sometimes with them are man-made stone implements, all of which have been washed by the stream into the same deposit (see pages 67, 68). Identification of the fauna helps to provide information concerning the climate and so a background to the tool-maker. For instance, finds of reindeer and mammoth bones indicate tundra-like conditions whilst finds of hippopotamus remains indicate a climate which left open water all the year round. An even more exact analysis can be made; the late Mr A. S. Kennard, for example, writing of freshwater and terrestial molluscan shells from peat-rafts in Terrace D at Farnham, Surrey[2] reported that 'the freshwater forms are dwarfed and conditions were unfavourable. The faunule . . . shows conditions probably similar to those of Lapland today.'

[1] Letter to author, 8 October 1957.

[2] *A Survey of the Prehistory of the Farnham District*, Surrey Archaeological Collections, 1939, prepared for the Society by K. P. Oakley, W. F. Rankine, and A. W. G. Lowther.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

Percolating acid rain-water has in many gravels completely leached out any lime salts and the upper layers seldom provide any bones. In the lower levels the acidity of the water has been so reduced by the time it reaches them that, as at Barnfield Pit in the 100-foot terrace gravel at Swanscombe in Kent, large numbers of bones, teeth, and tusks are preserved. Many of these however are quite soft and of the consistency of cheese or butter—this because the calcium carbonate content has largely been dissolved, only calcium phosphate and a trace of organic matter remaining. Such material upon being excavated and dried will warp and split unless it is given special treatment.

The Barnfield Pit section also provides examples of shell-deposits—in this case there are layers containing the shells of freshwater snails and molluscs, many shells being complete and unbroken. Important conclusions can be drawn from the existence of such beds: first regarding the general climate at the time when the shell-bearing animals were alive, secondly concerning the micro-climate, viz. the entirely local climatic conditions, and of the history of the site.

The preservation of the shells themselves admits of the drawing of two conclusions—that they are in the same position as that in which they first lay (any rolling would have broken them), and that their surroundings have always been sufficiently calcareous to preserve them.

So fragile are snail-shells (in which phrase are here included all molluscan shells) that land forms are unlikely often to survive, but conditions in water sometimes favour their preservation and they are found in flood-loams. Water-snails thrive in ponds and river backwaters where there is little flow, and in such undisturbed surroundings their shells, as they die, will accumulate in silts at the bottom: so long as the water remains alkaline they will be preserved and will form a small stratum. Should the water eddy and move them slightly they may be collected together in patches and the little deposits will appear as 'lenses' in another deposit, say of sand or loam, when seen in vertical section.

Some minor strata are built up as the result of certain animals inhabiting enclosed places—nesting jackdaws for example bring, in the course of years, enormous quantities of small sticks and other vegetable matter into caves and church towers, whilst owls, which have the habit of ejecting pellets, may litter the floor of a cave with these balls of indigestible refuse—rodent bones, beetle elytra, etc. The excrement of bats, consisting chiefly of insect remains, is also found in caves and may accumulate so as to form not inconsiderable strata.

Certain sea-birds, feeding on fish, so smother rocks on which they settle with their droppings that in areas where erosive rainfall is low guano is even quarried and exported as a garden fertilizer.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

Ants and termites build hills of earth and pine needles, beavers build dams (see page 93), but few animal activities result in lasting and effective constructions.

Hyaenas leave in their lairs deposits of dung heavily charged with remnants of eaten bone. This may be preserved in caves as coprolite, but the principal contribution of the carnivores to the material of new strata is their dragging into their lairs of the bodies of their prey: indeed wherever the bones of animals which could be expected normally to live in open country—the mammoth and the woolly rhinoceros for example—are found disarticulated in a cave the work of the hyaena may be suspected.

Seldom if ever is the complete skeleton of a hyaena found for, when he died, his remains were probably devoured by his fellows. In connection with hyaenas it may be worth noting that the females of some species of living hyaenas are in the habit, especially when with young, of scraping out for themselves hollows as 'nests'.

The remains of the cave-bear are also found in caves; the animal probably hibernated there, as do bears today.

As has been said above, animal remains do not normally survive except in protected situations; such are obviously provided by caves especially since, caves being usually in limestone deposits, any percolating water has lost its destructive acid content and the calcium of bones is thus preserved.

Whether stone implements are likely to have been made by the men or men-apes whose bones are found with them in some caves is for the archaeologist to decide: mere proximity in a cave of worked stones and the bones of, for example, the South African Australopithecinae is not necessarily proof of association. Wisely has it been said that palaeontology should be the hand-maid of stratigraphy and not the master.

Above are mentioned some of the activities of animals which assist in the building up of strata: they are insignificant compared with the destruction and erosion for which animals are responsible. Even solid rocks are attacked. Marine molluscs, such as *Pholas* (the piddock) and *Lithodomus,* drill and perforate rock so as to provide themselves with a sheltered retreat, whilst others pock rock surfaces by the secretion of acids.

Much of the extensive belt of country occupied and cultivated by Roman settlers in North Africa and many areas once farmed in the Near East are now sandy and unproductive semi-desert, for man's own herds of goats have so stripped the country of vegetation that plants are unable to recolonize the ground.

Deer in hard weather may ruin forests by stripping and eating the

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

bark from the trees. Sheep have for generations prevented the return of woodland trees and shrubs to chalk downland by eating young shoots as soon as they appear and rabbits have grazed some areas so close that the soil is open to erosion, which a thicker covering of vegetation would have prevented or delayed. Locusts, caterpillars, and other insects may rapidly defoliate and destroy vegetation and so leave the soil accessible to denuding influences. A plague of caterpillars may so strip a tree of leaves as to affect its growth—thus complicating the counting of 'tree-rings' for dating purposes. Wood-worm and beetle attack the timbers even of occupied buildings and eventually lead to their collapse.

Burrows honeycomb the soil—mice, rats, foxes, badgers, rabbits, moles, insects, and larvae all make their tunnels, removing earth and weakening the upper layers. Even birds such as martins, shearwaters, and puffins burrow into the ground so as to secure their nests, whilst some, the sparrow amongst them, peck at sandy surfaces and may remove the mortar from a wall.

Mites and other minute forms of life probably do not themselves move soil but they live in spaces in the soil and may add a little to its bulk by their dead remains. Mainly they act as destroyers of any organic matter, including plant roots, which enter the soil. Some species of bacterium can attack metal objects.[1]

The total effect in assisting sub-aerial erosion is immense.

The archaeologist must constantly guard against being misled by animal disturbance. His excavations must be such that he can immediately see where a burrow has once existed and how it has become filled—for material thrown out from or fallen into a burrow can seriously mislead when levels of finds are considered.

The original stratigraphical position of Stone Age and other finds in the Victoria Cave at Settle (Yorkshire), Kent's Cavern (Torquay), and other caves cannot be properly assessed owing to the activities of rabbits, foxes, and other tunnelling creatures. (Such tunnels, preserved in form though maybe filled with subsequently drifted material, are known to geologists as 'Krotovines' when found in loess.)

The activities of some animals have been described above: what of the burrowing earthworm? Charles Darwin wrote as long ago as 1881:[2]

> 'Archaeologists are probably not aware how much they owe to worms for the preservation of many ancient objects. Coins, gold ornaments, stone implements, etc. if dropped on the surface of the

[1] John Postgate, 'The Sulphur Bacteria', *New Biology*, No. 17.

[2] C. Darwin, *The Formation of Vegetable Mould through the Action of Worms, with Observations on their Habits*, John Murray, p. 164.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

ground, will infallibly be buried by the castings of worms in a few years, and will thus be safely preserved, until the land at some future time is turned up.'

As early as 1837 the same writer in a paper 'On the Formation of Mould' had drawn attention to his observation that cinders, etc. which had been strewn on the surface of a meadow 'were found after a few years lying at the depth of some inches beneath the turf, but still forming a layer'.

The earthworm feeds not only by drawing leaves and other vegetable matter into its burrow, but also by swallowing earth from which digestible matter is extracted. By some species the residue is thrown out above ground level as 'worm-casts'. Darwin calculated the weight of these casts as amounting in some cases to as much as 25 tons [*sic*] per acre each year: he recalled also the work of Hansen 'the Danish investigator' who 'pointed out that the weight of earthworms on pasture-land may be greater than the weight of livestock grazing it'.

The nature of the soil directly affects the number of worms and the less compact the soil the more can they burrow—sometimes to a depth of four or five feet when moisture and freedom from frost must be sought. Large numbers of worms are therefore to be found in disturbed ground, as at many archaeological sites. Worms, however, are unable to live in very acid conditions and few species where the ground is very wet: in these circumstances dead vegetation forms a thick carpet and, given certain circumstances, may become peat (see page 89).

The worm's mouth is so small that only particles of about 2 mm. and less in diameter are ingested and cast: this leads to a considerable sorting of the soil and has two important effects. First, the material of the worm-casts is very easily removed by rain-water and wind; and secondly this fine material tends to bury coarser matter which thus appears to sink into the ground.

Specific gravity does not affect the 'sinking'. A small object, such as a dropped coin, is quickly covered and even quite large stones may slowly become undermined and covered by accumulated casts. There must also be some real, as well as apparent, sinking of stones when underlying burrows collapse. Earthworms are known also to move quite considerable pebbles—up to about 2 oz. in weight—to cover the mouths of their burrows.

After 4¾ years Darwin noted that a layer of cinders was nearly an inch deeper from the surface than when last observed, but the sinking cannot continue long, especially where there is only a thin surface soil—as on chalk—for the worms feed only comparatively near the surface.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

The earthworms' burrows provide channels down which water drains, and assist the growth of plant rootlets. They also provide a means of access for air: in this they resemble those of the sea-shore lug-worm whose activities are responsible for the oxygenating of sand and the conversion of black iron sulphide into red iron oxide.[1] Bacteria are also given access into the soil and there assist in the decay of organic matter.

It may just be noted here that a species of worm was found at Verulamium living deeply buried in a first-century A.D. ditch which was sealed over by floors of successive buildings of the first to fourth centuries. In view of their isolated and sealed position it has been concluded that they may well have been direct descendants of worms living in Roman times.[2]

Hunting after the worms go moles, which usually make their burrows by forcing earth sideways and upwards with their shoulder muscles, but which often have to throw earth out in 'hills', especially when nesting. Earth so thrown out by burrowing animals has not infrequently betrayed the existence of an archaeological site, for with the loose earth are expelled coins, potsherds, etc.

Finally, among destructive fauna let us not forget the habits of man and his young, for it seems to be inherent in man's nature to destroy. Apart from damage caused by raids, sackings, and wars it seems natural for the adventurous to clamber over and disturb loose rubble: all manner of men will pull at a ruined building to extract useful timber, building and other materials, and just for amusement windows may be smashed or a tottering wall be pushed over. In the story of the stratification at a site of a ruined building this 'human element' usually has a place.

[1] G. P. Wells, 'The Life of the Lug-worm', *New Biology*, No. 22.
[2] R. M. Dobson and J. E. Satchell, 'Eophila oculata at Verulamium—a Roman earthworm population', *Nature*, Vol. 177, 1956.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

10

Flora

THE TWO-FOLD STORY of deposition and denudation can be told once again with relation to plant life. The last chapter, which related to animals, was largely concerned with disturbance. Let us then consider first the disruptive effects of vegetation upon strata; later something will be said of those effects of plant life which tend towards the building up and stabilizing of strata.

At any rate in temperate and arctic climates, the first forms of plant life (after algae, bacteria, and fungi) to colonize newly available surfaces are the mosses and lichens. By secreting acids they begin to break down rock surfaces: their decayed remains subsequently provide a root-hold and nourishment for higher forms of plant life. In spite of this, archaeologists who quite recently were applying rubber latex to the stones at Stonehenge with a view to securing plaster casts of the engraved representations of bronze axes and daggers were asked to endeavour not to kill the growing mosses—they were regarded as picturesque.

Carbonic acid (carbon dioxide in solution) is a common excretary product of all plant roots since it is formed during respiration. As was said above with reference to the formation of caves, this acid has a marked solvent action on calcium carbonate and to a lesser extent on calcium phosphate (the chief constituent of bone). Any plant growth therefore will assist in the breakdown of calcareous matter whether it be limestones, building mortar, or bone: at the same time, young root tips, which exude most acid, grow most densely around objects such as bone which furnish a ready supply of plant nutrients. It should be noted that the etched impressions of rootlets upon bone have more than once been mistaken for significant engravings.

As a result of capillarity and osmosis a growing plant can exert very great pressures: newly constructed pavements are often disturbed by the growth of quite lowly plants from spores and seeds in the soil below. Fungi will lift paving-stones, and many plants—the European thinks at once of bindweeds (*Convolvulaceae*) and coltsfoot (*Tussilago farfara*)—will grow through thick layers of rolled asphalt.

Even plants which have only one season's life to each generation and so achieve no great size can severely disturb a site. Many grow

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

substantial tubers, whilst those with a thickened central tap-root, for example the beet, may develop that root so that it is several inches in diameter and the amount of earth displaced weigh several pounds. Such a root in sandy soil may extend downwards for as much as five feet and the roots of most of the quickly propagating plants grow somewhat similarly.[1]

It is natural for wind-blown seeds to root in whatever cranny catches them: and as the plants or trees grow their roots will probe into any fissure which may lead to moisture. The growing roots exert lateral pressures and thus many incipient cracks are widened and many fragments loosened: the effects are to be seen everywhere but are naturally most spectacular when a tree has sent its roots into rock faces or into the stone-work of a building. If the tree dies or fails to secure a proper root-hold it will be blown down and maybe pull with it loose rock or parts of a wall.

Search for the 'picturesque', still cherished, as has been said above, has often resulted in the intentional planting of ivy by ruined walls so as to produce the 'ivy-clad towers' so beloved of the eighteenth and nineteenth centuries. Massive roots now both force apart and hold together the fabric's stones: it should be said that if the building is to be saved the plant's removal requires much skill and should not be attempted by the unpractised.

Most trees have two systems of roots, the ones penetrating deeply in search of ground water, the other spreading laterally to collect what moisture may fall on the surface of the ground. It is said that tamarisk roots were found at 100 feet below the surface when the Suez Canal was dug (though the possibility of their belonging to an earlier land-surface must not be forgotten) and in England the roots of oak trees have often been found penetrating and plunging down old wells. Everyone will have seen pavements lifted by the swelling growth of surface roots.

A few notes on the effect of trees on their surroundings may help in an understanding of the role of vegetation in stratification. In preparing the following paragraphs the writer has drawn heavily upon the work of Mr W. H. Ward.[2]

In the first place the water requirements of such trees as poplar, alder, and willow have been estimated as at least 12,000 gallons a year, whilst a well-grown apple tree may need about a third of that figure. The planting of trees has even been recommended for the drying of poorly drained land.

[1] Examples in the United Kingdom would also be the dock (*Rumex*), long-rooted cat's ear (*Hypochoeris radicata*), common burdock (*Arctium lappa*), and thistle (*Carduus lanceolatus*).

[2] W. H. Ward, 'The Effects of Fast Growing Trees and Shrubs on Shallow Foundations', *Journal of The Institute of Landscape Architects*, Vol. 11, 1947.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

Such large quantities of water extracted during those months when the leaves are on the trees result in a shrinkage of the ground (especially where it is of a clayey nature). Around trees it shrinks appreciably more than where grass alone is the ground covering and the zone of shrinkage extends as far as the most remote root, the length of which is usually greater than the height of the tree. Writing of London Clay Mr Ward says:

> 'Under grass the seasonal drying does not extend appreciably below four feet from the surface and brick houses founded three feet deep or more do not distort sufficiently to crack. In the presence of trees, however, the depth of drying commonly extends to ten feet . . . one solitary fast growing tree quite often causes a settlement of one or two inches . . .'

The result may be severe cracking of a building.

> 'During the winter rains the moisture in the ground is partly replenished, leading to a swelling of the clay. Thus at this time of the year the structures may rise partially and the cracks tend to close.'

The archaeologist will note that the collapse of a wall may be occasioned by the growth of a tree some distance away as well as by direct pressure from growing tree trunks.

> 'Trees planted near a house or impervious road surface are likely to extend their roots into the covered zone that receives no direct rainfall. Under these conditions they will, until wilting point is reached, tend to deplete the moisture locally with large shrinkage movements. In the course of shrinking the clay cracks . . . Cracks ½ inch wide at six inch intervals are commonly visible at the surface of a grass field late in the summer—and down them fall small objects . . . and gaps ½–1 inch wide have been encountered beneath foundations 2–3 feet in the ground.' (See Figure 11.)

Movement of a structure or heavy object as the result of wetting and drying of the ground is progressively downwards. Once a building or a stone has sunk it is unlikely to regain its former position, for clay and most other deposits are too plastic to exert, upon re-expansion, forces sufficient to lift it again. This sinking of heavier constituents therefore is proceeding at the same time that worms are bringing the finer particles to the surface. The trees themselves tend to have permanent basin-shaped depressions around them, maybe up to six inches in depth.

To the damage caused to archaeological sites (and, as will be seen,

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

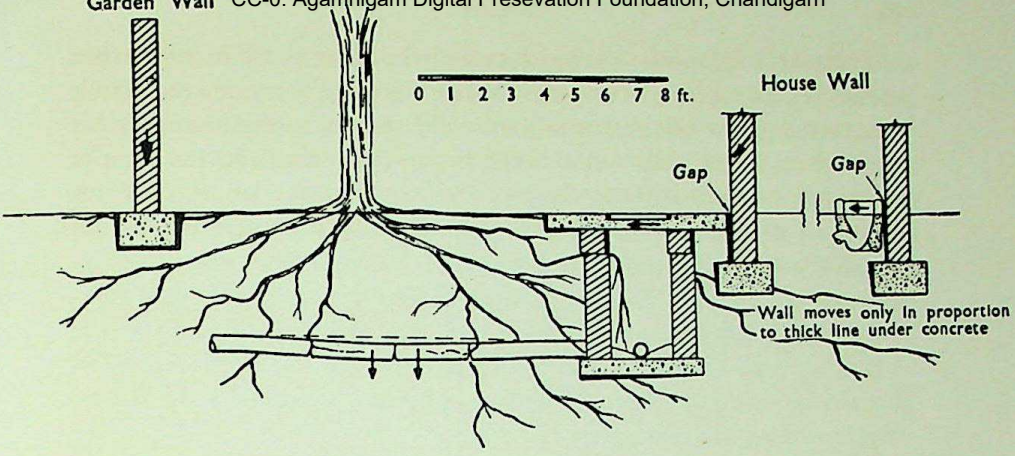


Fig. 11. The effects of fast-growing trees. A composite section of shallow foundations showing movements associated with drying action of roots in clay.

particularly to areas where there have been buildings) by tap-roots and spreading lateral root systems must be added that caused by suckers—those new growths above ground from underground roots which are one form of propagation.

Though vegetation may serve temporarily to hold rocks and stones from falling and soil from erosion, in the long view growing plants must tend to destroy and to assist gravity and the elements in their levelling. This becomes dramatically clear when a large tree is blown down in a gale: entangled in its roots many hundredweights of earth are pulled up to lie to one side of a hollow where the tree once stood. Such hollows with the earth-filled root-fan to act as a wind-break would present an inviting spot for a flint-knapper to squat: those who investigate discoveries of Mesolithic flints in what are claimed to be irregular huts with floors scraped out below the level of the surrounding ground should recall this fact and consider whether some 'post-holes' may not, in fact, be root-holes.

On the treeless chalk downs of southern England one can sometimes see shallow hollows, now grass-grown, with an irregular bank at one side. They are not the work of man but the sites where great trees formerly grew: in their falling, they pulled up earth to leave the hollows and, as they decayed, allowed it to fall from among the uptorn roots in an irregular mound at one side.

Amongst vegetation must be classed the fungi which live principally upon the remains of other plants and which include the badly-named 'dry-rot', which can rapidly spread through and destroy the timber in any damp building.

Such are some of the obvious mechanical disturbances caused by vegetation. Less apparent but more effective is the chemical denudation

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

of which it is the cause. In the process of the decay of fallen leaves (and indeed any part of a tree or plant) humic acids are formed: percolating downward in the ground it is they which are largely responsible for the formation of soils.[1] Any calcium or other basic matter in the ground is slowly dissolved away so that, whilst they may in fact form two parts of one and the same original deposit, the upper and lower parts of a deposit become different soil horizons and may differ in appearance as well as chemically. Such differing parts of a deposit must not be confused with strata which were laid down at different times.

Having read Chapter 4 the reader will not require to be reminded that the percolation of humic acids is constantly assisted by the falling of rain and its included carbonic acid.

From the consideration of the part played by vegetation in the disturbance and destruction of existing strata let us now consider its role in the formation of new strata.

Even the simplest forms of vegetation have that dual effect which has been noted so frequently above, for whilst the fungal hyphae of lichens effect some disintegration of the rock on which they grow, at the same time a firm hold is secured and the rough surface of the lichen catches and holds atmospheric dust, wind-blown seeds, and the mud from trickling water. The water itself is also held and thus made readily available to plant growths.

A principal result of the growth of plants is just such a catching and holding of loose earth (see pages 36, 99): a thick carpet of vegetation very considerably delays the erosive effects of wind and rain. Unless conditions have been very materially altered by the destruction of this vegetational cover itself, it will rapidly regenerate, a few seasons being sufficient for quite a large ploughed area to become recolonized and completely covered by new plants.

Many grasses (and also other plants) spread not only by generating new seedlings but also by sending out stolons horizontally above or below ground, long roots which sprout leaves and eventually new normal vertical root systems at intervals. Because they are being nourished by an existing system such lateral roots may extend for a considerable distance across stony and sterile ground. In this way, and also because some grass species tend to form 'mats' of living and dead vegetable matter, quite extensive areas of bare stone can be covered: once the mat has formed more vegetation can grow upon and amongst it.

Recumbent flat tombstones for instance are quickly buried if not regularly cleared: and, once the covering by mosses and grasses has

[1] See I. W. Cornwall, *Soils for the Archaeologist*, Phoenix House, 1958. The soil scientists have not yet made clear exactly what is the nature of these humic acids, or exactly defined 'humus'.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

begun, loose matter (rain-washed, wind-blown, animal-disturbed, etc.) is constantly caught amongst the stems.

The use in Ireland and elsewhere of the word *turf* to indicate peat (see below) must not lead to confusion with the word as used in southern Britain, where it is given to the closely interwoven tangle of living and dead grass and grass roots which occupy the surface of the ground and the first two or three inches below it. So matted can this turf become that it may be cut and lifted in pieces: as such it has often been used as a rough building material or, relaid like a carpet, as a revetment against the erosion of banks of loose material.

Such (southern) turf, when it lies on the surface of the ground, is subject to the same processes of decay as any similar vegetation, and is eventually dissipated into air and water. When it is buried, however, even in strongly alkaline surroundings it may remain recognizable for very long periods. For example, natural or artificial 'turf-lines' are frequently to be seen in archaeological cuttings through earthwork banks, where the natural rock and the material artificially thrown up over the ancient turf are both chalk. Turf-lines may also be seen sometimes in sections through the material filling ancient ditches. The inference to be drawn is that there was a pause in the silting during which a turf of grass had time to grow upon the primary silting but, in interpreting the stratification of the section, it must be borne in mind that grass grows quickly and that the secondary silting may have taken place almost immediately: perhaps within the same year.

Vegetable matter which is only thinly covered by alkaline rock and soil will rapidly disintegrate, largely as a result of oxidation and the activity of bacteria, but when it is deeply buried oxygen is excluded and few bacteria survive: thus the turf is more or less preserved. Such humic acids as are formed apparently act upon the calcium carbonate of chalk to produce insoluble calcium humates. It may be noted incidentally that, for reasons which are not entirely clear, peat is remarkably free of bacteria (and in some forms is even used as an antiseptic dressing).

Growing plants, of course, actually increase the amount of solid matter at the site of their growth, for they collect minerals not only from the soil but also from ground-water: further, by photosynthesis, they extract carbon from carbon dioxide in the atmosphere. Many plants can grow without actual contact with the soil: they may send roots amongst the decayed remains of other plants or grow actually floating in water.

It is the killing of the vegetable carpet naturally or artificially which exposes loose soil to wind erosion. Examples are the American dust-bowls resulting from over-cropping and the periglacial areas where

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

intense cold kills the vegetation and leaves extensive tracts of tundra from which the wind can remove the materials of loess (see page 32). Excessive tree-felling and overgrazing by herds of cattle and sheep produce similar effects.

Erosion by surface-water is also accelerated by the removal of the vegetational carpet—for each blade of grass helps to slow down the downhill progress of rain-water, and to catch any material which has begun to move.

As has been mentioned, some success has been achieved in man's attempts to stabilize advancing sand-dunes, by the planting of a coarse spreading marram grass or by the introduction of young firs and pines amongst a 'thatch' of twigs and brush-wood: once established, the trees themselves by periodically shedding their leaves ensure the permanence of a protective vegetational layer above the loose sand. The deeper roots also help to consolidate it. Tree-roots and turf also tend to hold loose scree from sliding downhill.

Fallen leaves and stems of vegetation often serve to protect living plants below from damage by frost. New shoots of bracken for example are usually seen coming up through a tangle of old stalks: the tangled mat tends to grow in thickness.

By the shedding of dead leaves and branches and the final collapse of the main plant trunk or stem, vegetation makes a major contribution to the formation of new strata: except where for instance coal is concerned, in geological terms such strata tend to be impermanent but they are of great importance to the archaeologist.

Whether the shed leaves, etc. are able to form a lasting or a very temporary layer must depend upon a number of circumstances. In very dry conditions the vegetable matter falling upon the surface of the ground will quickly be desiccated, turned to dust, and blown away. On the other hand in protected places dry conditions will preserve: one thinks at once of wooden furniture in Egyptian tombs and the straw-mat linings and baskets found, also in Egypt, in grain-silos sunk into and eventually covered by dry sandy earth.

More usually fallen vegetation is subject to the effects of varying amounts of moisture. Given access of air the fallen twigs and branches together with a regularly renewed carpet of deciduous leaves are normally attacked by fungi and bacteria and, in decaying, form humic acids which are carried by rain into the soil below: there they assist in the disintegration of soil minerals, but where moisture is sufficient a substantial layer of leaf-mould and humus—a mixture of organic and inorganic materials—may be built up.

The same causes are at work in the building up of peat though conditions of extreme wetness are required. In such circumstances

V. The result of erosion by torrential rain; material for substantial new strata in Hong Kong.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

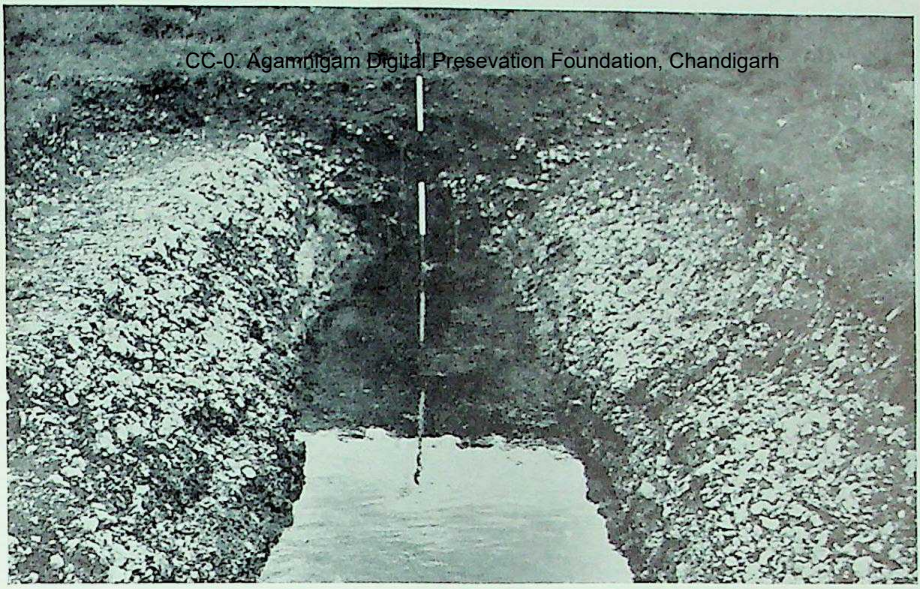
VI. ABOVE: An ancient ditch completely filled with natural accumulations before it was excavated and photographed in July 1950. Note the erosion of the upper edges.

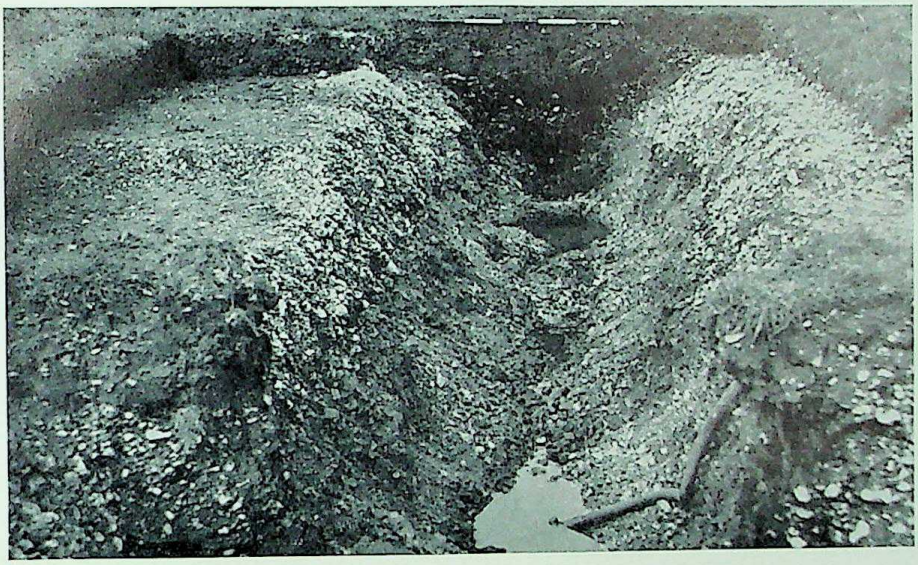
OPPOSITE, TOP: The same ditch in April 1951 after it had been left open and exposed to the elements.

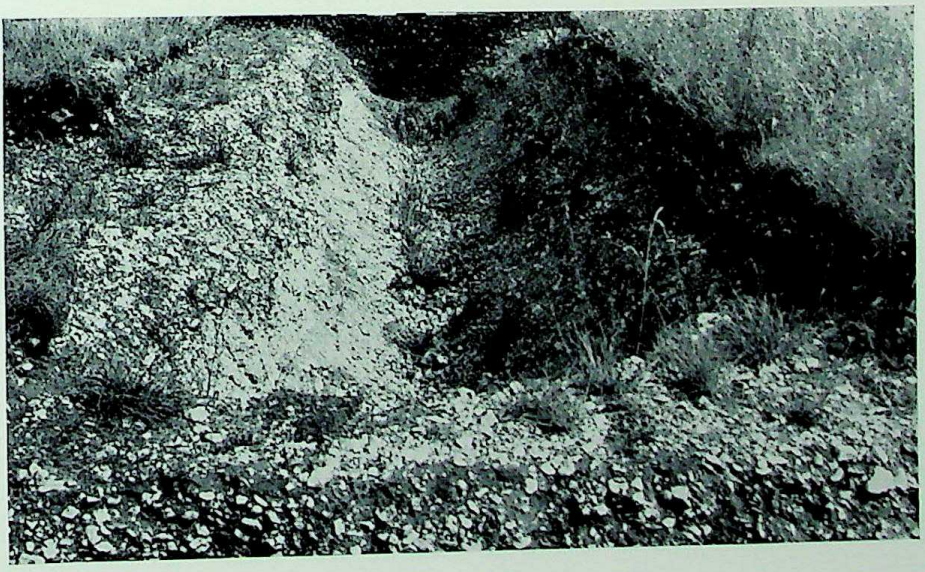
CENTRE: Later in the same month the sides have once again begun to collapse.

BELOW: By June 1952 the bottom was covered with fallen material and vegetation had begun to grow.

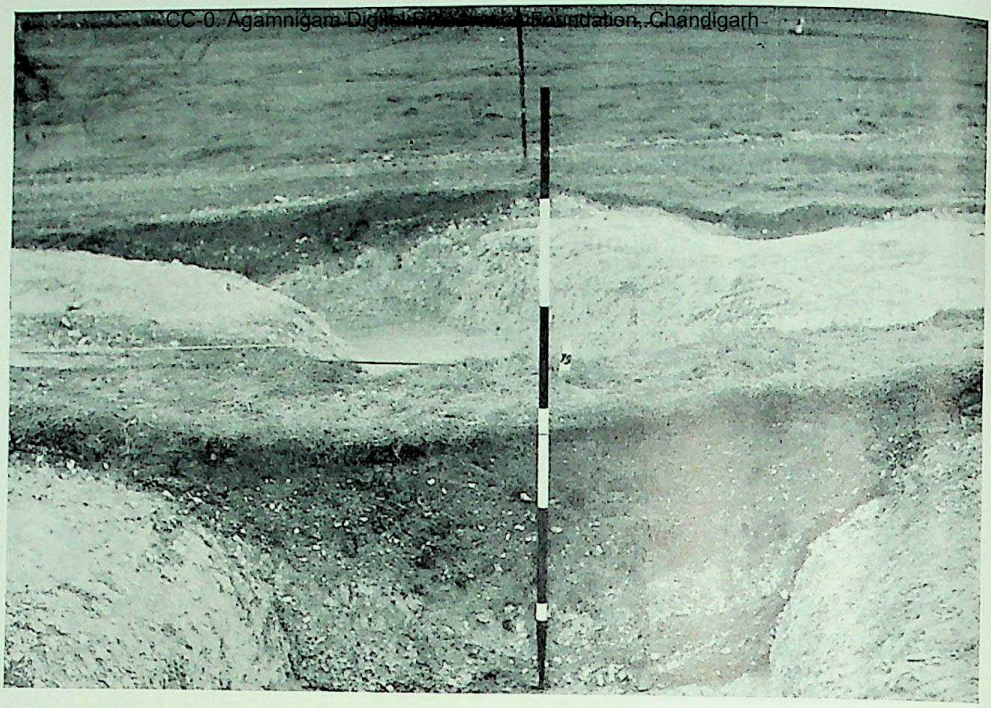
CC-0. Agamnigam Digital Presevation Foundation, Chandigarh



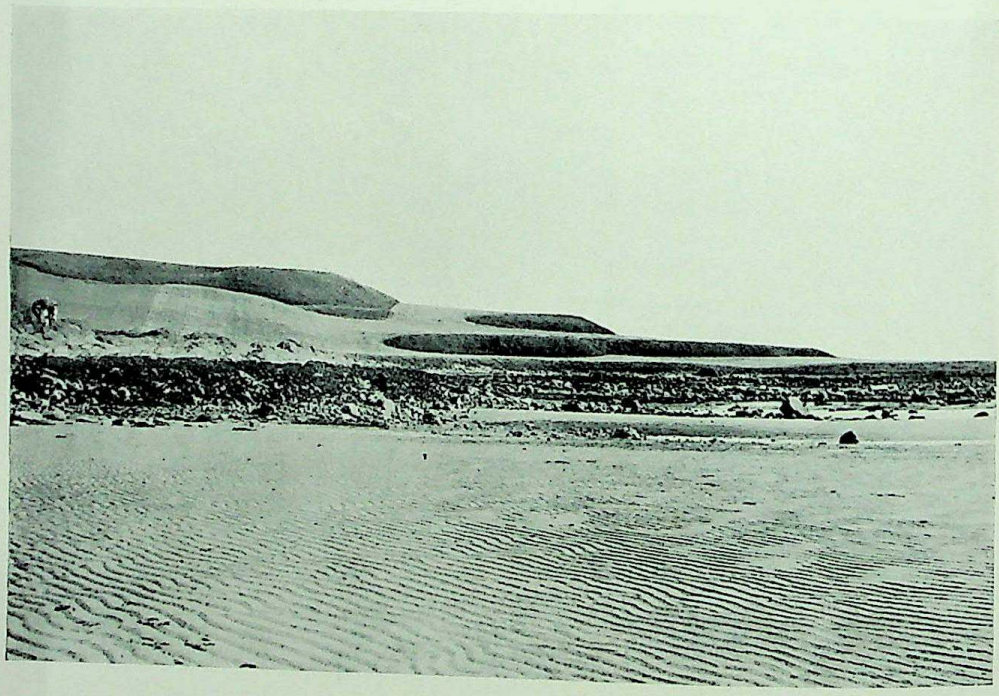




CC-0. Agamnigam Digital Preservation Foundation, Chandigarh



VII. This photograph of a barrow ditch in the course of excavation shows the typical rounded edges pictured in Fig. 4. Note the coarse first filling at the bottom of the ditch.



VIII. Raised beaches at Elie, Fife, Scotland, which have been elevated as the result of isostatic movement.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

vegetation normal to the latitude in question will not survive but the area will be colonized by plants specially adapted to live in boggy ground. Before we consider the formation of peat further, let us turn to those plants which live actually in water.

Except where wave or current action is too strong the ground at the margins of fresh water is usually the habitat of a specialized flora. Reeds and sedges, irises and such plants root in the soft mud and extend laterally and towards deeper water by sending out roots from which new shoots grow: dead leaves tend to sink to the bottom of the water but to remain attached to the root system so that new growths grow above and among them. At the same time the plants tend to prevent any removal of the muddy ground by movements of the water and to retain amongst the foliage any new mud which may be washed to the area.

These are the conditions in which fen peat is formed. Although of limited distribution this fen peat is not uncommon in areas which accumulate water from surrounding chalk; the water is alkaline and thus bone and antler may be preserved.

The more widespread vegetational deposit is bog peat, which forms at higher altitudes in conditions of cold, acid dampness rather than actually under standing water. In bog peat bone is destroyed but skin and other non-calcareous animal matter may survive.

The rather special case of fen peat will be described first.

Being under water the remains of dead plants and leaves are protected from a great many of the bacteria and other destructive agencies so that they remain more or less recognizable over very long periods. Slowly then ponds, canals, and any expanse of water in which there is not too destructive a current are clogged by vegetation: eventually little new inorganic material will penetrate to the centre of what was once a lake but so long as the area continues to be sufficiently wet new water-plants will grow above the remains of former generations. In this way layers many feet in thickness may be built up. In due course, the source of water probably having been somewhat diverted, the site will allow damp-loving shrubs and trees, such as alder, to take root, and finally the normal vegetational cover of the district will extend over the whole area. Later the deposits may be covered with others of quite different origin. The lower layers obviously by reason of the weight above them become more and more compact and expel a large proportion of their water content. (In much the same way were the coal seams formed in extensive swamps.)

When such peaty deposits are examined it is found that they provide a complete record of any changes in the vegetational cover of the area during the period when they were forming. Perhaps one is concerned

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

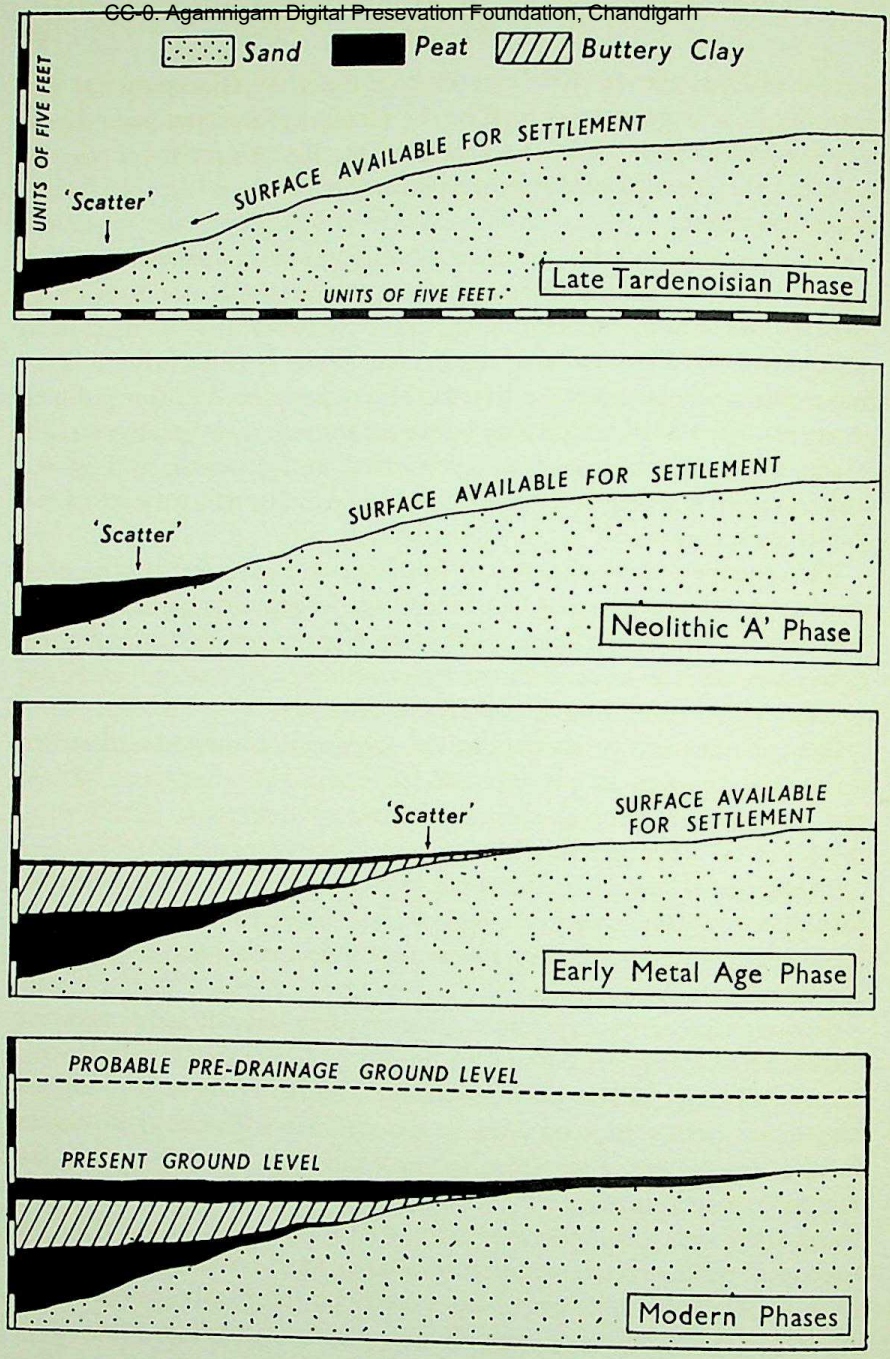


Fig. 12. Peacock's Farm: these diagrams illustrate the manner in which growing peat serves to seal in scatters of archaeological material. On the left of each picture, where the level of the peat is rising, scatters of different ages are conveniently separated. The surface of the sand hillock available for settlement is slowly reduced and it can be seen how, on the right-hand side, peat may seal on one surface artefacts of several different dates.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

with a hollow excavated by ice during the Last Glaciation: at the bottom of the deposits may well be the remains of the first plant forms to colonize the basin after the retreat of the ice. Above them may be expected the remains of different plants which grew when the climate became warmer.

Amongst the remains of water-loving plants, however, one can expect also to find the pollen of trees which could not have been growing actually at the side of the lake. Remarkable as it may seem the pollen shed by many trees and other plants is extremely durable: those plants whose seeds are fertilized by wind-carried pollen produce great quantities of it, which may be blown for several miles. Eventually it will fall and some will fall upon the lake or swamp and be incorporated in the peat layer so that evidence of the former state of the countryside is recorded at the appropriate level.

The sequence of 'pollen zones' has been worked out for a number of areas[1] and some progress has been made in providing dates in years for different horizons. Dates have even been given to some Bronze Age implements as a result of the study of pollen in peat still adhering to them many years after their original discovery.

Changes, gradual or sudden, in the succession of deposits of pollen will reflect changes in the flora of the surrounding dry land. These may result from general climatic fluctuations or from purely local causes: those resulting from human activity are mentioned on page 102.

Evidences of this kind, incidentally, are not exclusively confined to peat deposits, for ancient pollen slowly being washed down into comparatively dry ground has been found and conclusions regarding former forest cover deduced.[2]

Before considering any other kinds of plant deposit let us turn for a moment to a site well known to British prehistorians, viz. Peacock's Farm at Shippea Hill in the Cambridgeshire fens, where the clogged courses of former streams show as meandering dark marks in lighter ground. Figure 12, taken from the excavator's report,[3] illustrates the sequence of stratification.

On what was once the exposed surface of a sand-ridge relics of various periods of settlement were mixed; the historical sequence of these finds was largely settled by a study of the relative positions of the comparatively few objects which fell into 'growing' deposits of peat and mud in a stream which was gradually being choked up. The sand-ridge was accessible to men of the Late Tardenoisian period and

[1] See H. Godwin, *The History of the British Flora*, Cambridge University Press, 1956.
[2] G. W. Dimbleby, 'The Ecological Study of Buried Soils', *Advancement of Science*, XI, No. 45, pp. 11–16, 1955.
[3] J. G. D. Clark, H. and M. E. Godwin, and M. H. Clifford, 'Report on recent Excavations at Peacock's Farm, Shippea Hill, Cambridgeshire', *Antiquaries' Journal*, XV, 1935.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

remained so during the succeeding Neolithic. Though peat had covered part of the sandy surfaces the concentration of finds suggests that Neolithic man particularly favoured the contemporary edge of the peat. Subsequently the district seems to have been flooded and inaccessible. Under the spreading water peat no longer formed but clayey mud accumulated: it is sterile so far as archaeological remains are concerned. This deposit is known to merge into estuarine or marine silt lower down the silted channel. When the waters receded peat again began to form and at the same time man again occupied the ridge.

The excavator drew attention to the fact that 'the extent of the slope of the sand-ridge occupied by each culture affords a good check on the reality of the stratigraphy, no Early Bronze Age objects, for example, occurring on the sand slope below "buttery clay", no Neolithic shards occurring below more than 27 inches of lower peat, and no microlithic (Tardenoisian) material occurring below a certain black sandy layer within the lower peat'.

Some other conclusions incorporated in the report are worth mentioning since they indicate the kind of information which can be secured from a study of the natural deposits in which the human artefacts were found:

(a) from molluscs collected near the top of the lower peat it was inferred that the climate was probably warmer than today, possibly with less severe winters.

(b) The peat below the finds of Mesolithic material included much pine and hazel: both fell off in quantity after the arrival of Mesolithic man, to be replaced by much alder, which moisture-loving tree was dominant at this site during the Neolithic occupation.

(c) There were indications that the lower peat surface, before it was covered by the clay, was colonized by a dense growth of trees and bushes—corresponding to the later stages of 'carr' development in present-day fen vegetation.

(d) Between a depth of 16 inches and the top of the upper peat were signs of a return to aquatic conditions: there were sedges, reed-mace, and pockets of shells of water-snails.

(e) At the base of the upper peat where it lay on the buttery clay the plant remains suggested 'conditions approaching shallow open water'.

(f) The buttery clay deposit provides evidence of a marine transgression, probably fairly wide-spread and therefore recognizable

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

elsewhere and useful in providing relative dates. The report in fact reads: 'Positive evidence of marine transgression is given by the returning wet conditions at the top of the lower peat and the semi-marine conditions of the fen silts and clays.'

Whilst we are concerned with the East Anglian fenland it may be of interest to turn aside for a moment to note an amusing reversal of the relative levels of two natural deposits. Describing traces of a Roman bridge E. J. A. Kenny wrote:[1] 'The extinct rivers [of parts of the fenland] are described under the name of "roddons". A roddon in its present form is a raised bank of laminated silt or shell marl which runs in a meandering course through the Fens. These banks represent the alluvium deposited by the rivers in the channels. The raised position of the banks relative to their surroundings is due to differential shrinkage. The surrounding peat has shrunk by reason of the intensive drainage of modern times, while the silt or marl has not shrunk, with the result that what was once the bottom of the river is now the top of the roddon, for the raised banks of the stream have been let down by the shrinkage of the peat beneath them.'

Major Fowler wrote:[2] '. . . the peat of the fens has been shrinking during the last 100 years of intensive power-plant drainage and cultivation at the rate of about one inch per year and about one quarter of an inch per year during the previous two hundred years of windmill drainage.'

These extracts serve to emphasize the great importance to the formation of peat of a high content of water within it. Indeed the growth of additional layers is closely dependent upon water-level.

So long as there is sufficient moisture available either through direct access or as the result of capillary rise within the spongy mass of dead vegetation new growth will continue. The clogging of streams by sedges, reeds, and rushes will encourage flooding and meandering of the stream and will halt the removal of silt: the marshy peat will continue to increase in thickness either until the stream cuts a new channel and drains the swamp or until other factors come into play.

At Thatcham in the valley of the Berkshire River Kennet, in an area where extensive remains of the Mesolithic period have been found, an important change in local conditions has been ascribed to the work of beavers. It would seem that some way downstream beavers built a dam which raised the level of water in the valley by several feet: the

[1] E. J. A. Kenny, 'A Roman Bridge in the Fens', *Geographical Journal*, No. 82, p. 434, 1933.

[2] G. Fowler, 'Old River Beds in the Fenlands', *Geographical Journal*, Vol. 79, 1932. This paper also notes that in some cases parish boundaries lie along the course of roddons, which represent the natural drainage of the Fens. At the time of the drawing of the boundaries no doubt they held running water.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

peat was flooded by a lake of alkaline water in which lived not only shell-bearing molluscs but also plants of the Chara family which extract carbon dioxide from water causing calcium carbonate to deposit. The plant stems became encrusted and eventually a stratum of Chara-marl was formed. At the same time the spreading waters of the lake provided a very large surface for evaporation so that calcium carbonate was deposited with the shells and plant skeletons on the floor of the lake. A fairly thick bed of 'shell-marl' was the result. At a later stage the water-level fell again and a second bed of peat was able to form above the marl.

Plant remains, like animal remains, lead to conclusions with regard to climate. The well-known series of gravels at Farnham, Surrey—rich in Palaeolithic implements—provide an example: Rankine[1] noted in the gravels of Terrace D (50′) 'rafts' and lenses of peaty material. These yielded remains of flowering plants and mosses as well as fresh-water and terrestial molluscs. The flora testifies unmistakably to a cool climate: all the plants specifically determined now extend into arctic regions and belong to the floras which in temperate regions live only on upland moors and mountain slopes.

Except for the plant remains from Farnham we have been concerned largely with peats formed in low-lying marshes where the plants involved are largely reeds, *Phragmites*, and trees like alder—but given damp and acid conditions peat of a rather different kind can form high up on the sides of mountains. The principal plant then is the sphagnum moss which is responsible for the extensive spreads of blanket bog in Ireland and the Scottish Highlands. Certain bog-grasses also play an important part, as does heather, in the early stages: for whilst heather has a preference for well-drained acid soils its wiry stems are slow to decay and may form a mat over which the peat mosses and grasses may eventually grow. In areas of heavy annual rainfall the bog peat may attain a thickness of many feet, and, incidentally, may destroy fertility of the ground and cause abandonment of a site: in the island of Lewis, where the peat has been stripped for fuel, crops can now be grown on the original soil beneath.

Lethbridge writes:[2] 'I have seen Bronze Age cairns on Eriskay whose existence was unguessed before the peat above them was removed.' In the same work he reports: 'Five feet of peat grew round the stones of the great megalithic monument at Callernish, which itself stands on the top of a hill. Pine forests died and their tree stumps were buried deep beneath the blanket.' Moorland bog peat like marsh peat records the history of vegetation at the place since vegetable matter

[1] *A Survey of the Prehistory of the Farnham District*, Surrey Archaeological Collections, 1939, prepared for the Society by K. P. Oakley, W. F. Rankine, and A. W. G. Lowther.
[2] T. C. Lethbridge, *The Painted Men*, Andrew Melrose Ltd., 1954.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

first began to be preserved: deeply buried by later growth there may be birch and pine tree remains from the beginning of the post-glacial period but Lethbridge reminds us 'Peat does not necessarily take a long time to grow. I found several inches of peat inside an Eskimo house in Baffin Land, which produced an iron harpoon which was probably less than a hundred years old.'

Wet and acid conditions do not serve only to preserve vegetable matter. In fortunate circumstances animal matter is also preserved. Although the calcium carbonate of bone is dissolved the skin proteins are not destroyed by acid: as long as conditions in a bog remain the same the skin will be preserved though of bone there will remain only calcium phosphate and some organic matter.

Thus were preserved for discovery the Early Iron Age man at Tollund in Denmark—with the plaited leather hangman's noose around his neck and identifiable food remains in his stomach—and the little girl who was blindfolded and thrown to drown in a stagnant mere at Domslandsmoor in north Germany.

Both types of peat—acid and alkaline—have been responsible for the preservation of much archaeological material—Mesolithic bone and antler artefacts,[1] prehistoric clothing, and 'corduroy roads' of brushwood laid to provide a surface to boggy ground. Elsewhere none of these substances would have been preserved.

Within the peat and distinguishable in a section there can often be seen perhaps more than one band of disintegrated peat: such a layer has become known as a 'grenz-horizont'. These layers mark a retardation in the growth of the bog peat and attempts have been made to correlate such horizons with those in other bogs: the retardations however are not necessarily synchronous. A change in the bog may indeed be the result of a general decrease in rainfall but it may also have other causes of purely local character: the collapse of a natural dam might easily alter the water-level, whilst a dry surface may be either the reason for or the result of attempted agriculture.

Whilst we are concerned with deposits of vegetable matter it may be as well to refer briefly to certain mounds of natural origin which have occasionally been mistaken for man-made barrows. Gordon describes them in the following paragraphs.[2]

'In the strict sense of the term, a Dartmoor "mire" is quite distinct from the conventional bog. It is mainly caused by numberless springs, the ooze from the hills, which, debarred from immediate escape by the broken nature of the ground and the impervious granite beneath, is held by the soil as by a sponge. The green excrescences, known as

[1] e.g. at Starr Carr, Yorks.
[2] Douglas Gordon, *Dartmoor in all its Moods*, Murray, 1931.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

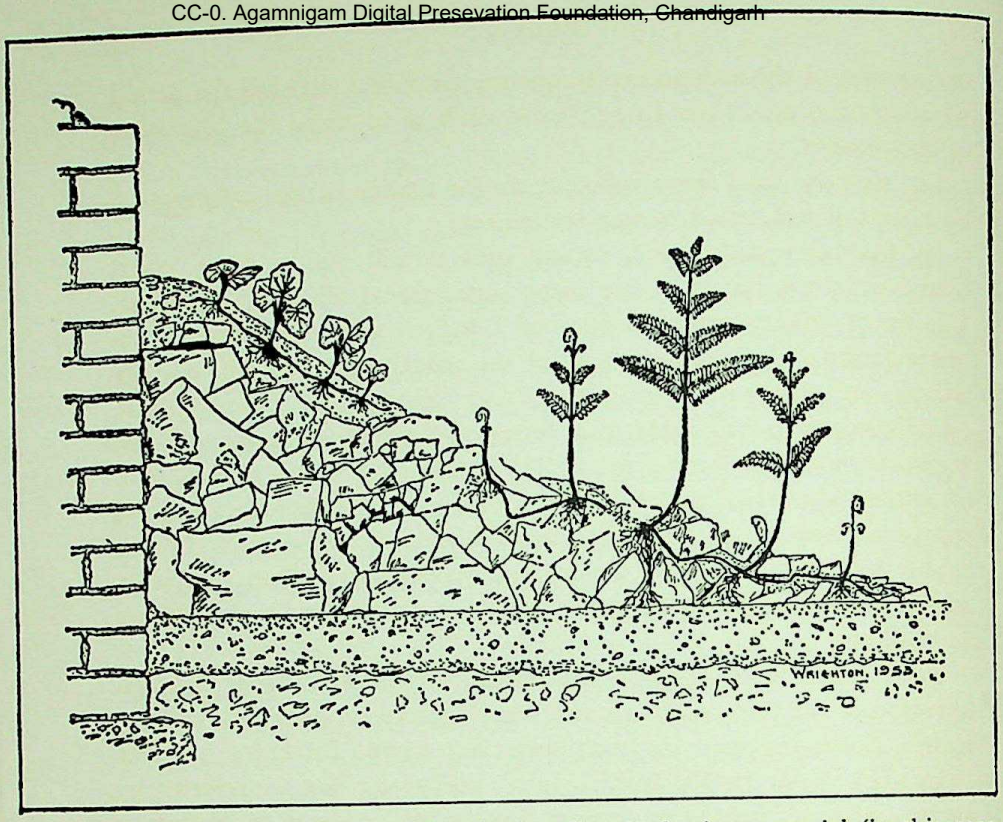


Fig. 13. Plants (coltsfoot and bracken) sealing in broken material (in this case bomb-rubble) and collecting fine material on top of coarse.

"stables" among the country people, are nothing more than the spring heads, where the turf has been lifted by the pressure of the water. These at times are raised to the height of several feet, forming the green mounds . . . When, as frequently happens, a spring dries up permanently, these mounds remain, gradually assuming the form of solid barrows, the sphagnum moss of which they are originally composed being replaced by ordinary moorland grass . . .'

The peat-bogs are entirely different from the 'mires' which lie in hollows mostly. The peat lies mainly on high ground, covering enormous areas.

Of some importance are strata resulting from the accumulation of the siliceous skeletons of diatoms—minute plants of which there are many kinds each living in narrowly confined conditions of acidity. A deposit of diatomite overlies peat in the valley of the River Bann in Northern Ireland: it indicates that following the swampy conditions in which the peat grew there was an increase in the depth of water and probably also an increase in acidity.

Charcoal and wood ash within diatomaceous earth on the fringes of Lough Beg in Northern Ireland have been related to the Neolithic

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

occupation of the area and consequently provide a date for the period when conditions in the Lough were such as to allow the formation of the deposit.

Let us now turn for a moment to the matter of the colonization by plants of a deserted human settlement.

As has been said above, certain grasses will rapidly form 'mats' over bare stone but there are many other plants which soon appear. The first plants to arrive in bombed London[1] were those with wind-borne fruits and especially those of the parachute type—e.g. rosebay willow-herb, ragworts, groundsel, and thistle. The rosebay, once established, also vegetates and produces underground shoots: the ragworts have a preference for well-drained sites and will thus flourish on clinker and brick rubble. Coltsfoot also likes waste places and has wind-blown seeds: its scaly underground stems creep for yards beneath rubble (see Figure 13). In the damper basements bracken sporelings and prothali found a footing; also brought by the wind were willows and sallows.

Some seeds were brought by animals (many seeds pass through horses) and others from boots and wheels found root between cobble-stones. Seeds dropped by birds were responsible for the growth of elder high up on ruined walls, whilst everywhere mosses, liverworts, algae, and fungi helped to prepare the way for invasion by flowering plants.

John Ray wrote of the plant London Rocket: 'In 1667 and 1668, after the City was burned, it grew very abundantly on the ruins round St. Pauls.'

The notes are about a city which has continued to be occupied and has been rebuilt. It is obvious how quickly the whole area would have been smothered with plant life had it been, like many towns before it, completely abandoned.

[1] R. S. R. Fitter and J. E. Lousley, *The Natural History of the City of London*, Corporation of London, 1953.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

11

Human Settlements

BRIEF MENTION HAS been made in the chapter on Fauna to the activities of man, but the role of man (today one of the principal agents in changing the landscape) as an agent in stratification must be considered much more fully.

As early as the period of the Neolithic in western Europe it was realized that flint was to be found in seams in the chalk. No doubt when outcrops on the hillsides were exhausted, shafts were sunk from the tops of the hills so that good workable flint, unaffected by frost, might be reached: the chalk downs in southern England are in many places honeycombed with such shafts and lateral tunnellings.

Space does not allow a full consideration of man's activities as the maker of tunnels and dams, of his building of sea walls, his diversion of streams, and his many reasons for and methods of levelling and moving rock and soil. Some thought however must be given to the work he must undertake in connection with even simple forms of agriculture and with the establishment of a settled way of life in place of nomadism, and to the stratified deposits which may result.

Deposits (and denudation) following man's activities are obviously on a very much smaller scale than those resulting widespread from natural agencies, but the gravitational laws governing the formation of strata remain the same.

Let us consider some of the effects of man's disturbance of the soil. In the first place mere temporary camps will probably involve the clearance of light scrub and the trampling of vegetation: normal regeneration will usually ensure the growth of a new protective covering to the ground but it may be that the surface will be exposed for sufficiently long to allow of the removal of some soil through erosion by wind and rain. Well-beaten tracks and paths are similarly subject to erosion and on hillsides may be cut down into deep gullies.

The results of light 'scratch-tillage' or the hoeing of the ground for the growing of crops are essentially the same—once the surface is broken and cleared of its natural vegetational cover it is easily further broken up and washed downhill. With the advent of the plough and the deeper disturbance it caused this downward movement—soil-creep—became much faster. The effects can be seen wherever sloping

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

ground has been ploughed—particularly clear are the evidences of prehistoric agriculture on the slopes of the chalk downs in southern Britain, where field banks and boundaries are still clearly visible. Such banks were not intentionally made but are a result of a gradual downhill movement of the soil. They are the cumulative results of the action of frost and rain in breaking up and transporting soil and tend therefore to increase in size with increases in the slope of the ground. Their formation is explained in Figure 14.

(a) shows a wooded hillside along the side of which runs a path.

(b) shows the vegetation cleared for farming except on either side of the path where trees, shrubs and unploughed lesser plants continue to grow and to serve as a boundary to fields above and below. Loosened soil has begun to wash downhill, but is retained by the vegetation and is beginning to form a bank at x.

(c) All trees have gone and a covering of grass has stabilized the soil which still lies in banks. At x the bank has grown by the once almost continuous addition of new hillwash and a bank has formed above the pathway. Such increases in soil depth produce what are known as positive lynchets. At y the same thing may be seen, but at the places marked z the soil has been removed and not replaced: the ground level has been lowered so that there is a second and downward bank below the path. Banks caused by the removal as opposed to the additions of soil are called negative lynchets.

It is obvious how ploughing may assist both in the destruction (at z) and the protection (at x and y) of evidence of earlier occupation. Once a layer of turf has formed over the banks further movement will be arrested or delayed.

In mediaeval times in Britain efforts were made to improve the texture and content of the ground in which crops were to grow. Pits were sunk through the peat of the Fenland so as to obtain clay for spreading on the surface, whilst in those areas where Tertiary sands lay above chalk, shafts were sunk to obtain that chalk so that, broken up and distributed, it might serve to reduce the acidity of the sandy soil. Such shafts are still met with as 'dene holes'.

In most areas where the chalk is near the surface either the soil is a 'rendzina'[1] or else calcareous deposits are covered by a non-calcareous stratum of 'clay-with-flints'. In either case a farmer would seek to spread some alkaline chalk upon the surface—a process known as marling. Slowly this spread will be worked into the ground and the chalky matter will be leached out of the upper parts: thus in many

[1] See I. W. Cornwall, *Soils for the Archaeologist*, Phoenix House, 1958.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

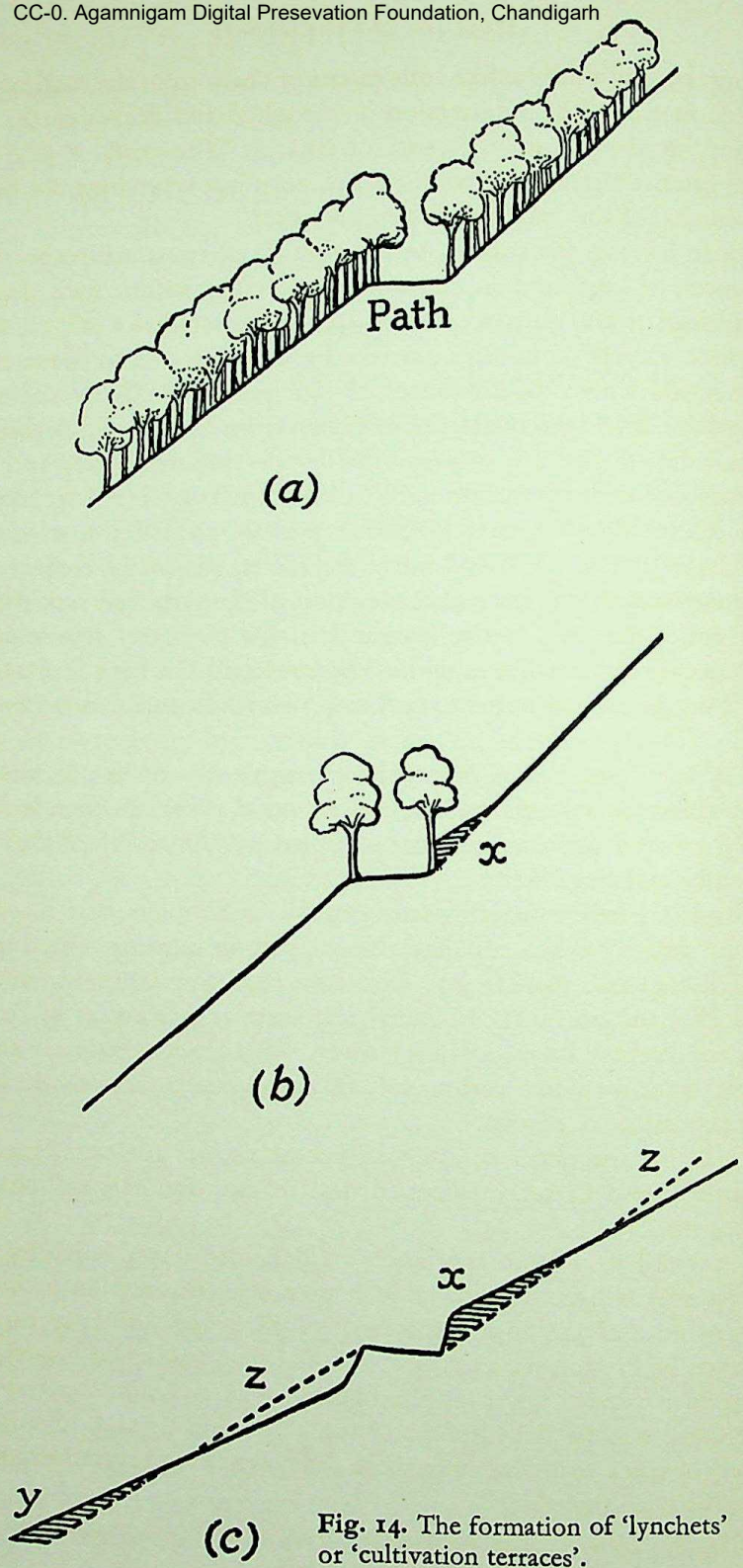


Fig. 14. The formation of 'lynchets' or 'cultivation terraces'.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

cuttings through the surface soils pieces of chalk from the marling may be seen as a band at the junction of ploughed and deeper earth.

Pliny, in about A.D. 70, wrote of Britain: 'The chalk is dug from shafts often 100 feet deep with narrow tops but spreading out below. The effects [of the marling] last eighty years.'

Before leaving the subject of agriculture we must return briefly to evidences to be found in deposits of peat, for within such deposits archaeologists and palaeo-botanists have found evidence of early forest clearance. Layers of ash and charcoal have been found to occur at just those levels where the frequency of tree pollens suddenly decreases: at the same levels the quantities of pollen from grasses and herbaceous plants increase and are accompanied by pollens from corn and such cultivation weeds as the plantain (see Figure 15).[1] The inference has been drawn that the first Neolithic farmers cleared the ground of vegetation by the 'slash and burn' technique, whilst the frequency of evidence showing a natural regeneration of the flora and reduction in corn pollen has led to the assumption that the early semi-nomadic farmers cleared a small area within the forest, tilled it for a few seasons, and then, so as to improve the yield, moved to and cleared another site.

At a very early stage in prehistory man's use of fire became the cause of lasting deposits, and patches of wood ash are frequently found buried by later deposits in caves occupied by Upper Palaeolithic man in France and elsewhere.

Wood is partly mineral, partly organic in content: if it is burned without much oxygen reaching the fire carbon remains—often in the form of charcoal. Few, if any, organisms feed on pure carbon and the ashes of a fire are likely to remain. If there is full access of oxygen even the carbon in wood burns away, what does remain consisting largely of acid-soluble carbonates: in calcareous conditions therefore even this ash may remain.

Whilst fire can occur naturally as a result of, for instance, lightning, vulcanism, and bacteria-generated heat, it can normally be regarded as man-made.

A low red heat (800° centigrade) will redden baked earth by converting yellow-brown limonite in it to red haematite: the process is irreversible and the local reddening of rock and soil may provide evidence of the former existence of a fire. The baking of clay vessels to produce pottery involves the same change and if the pot is well fired there will be dehydration of the clay minerals and edge-fusing (sinter) of silica particles: since these changes are not reversible pottery is almost indestructible.

[1] J. Iversen, *Landnam i Danmarks Stenalder*, Danmarks Geologiske Undersøgelse, 1941.

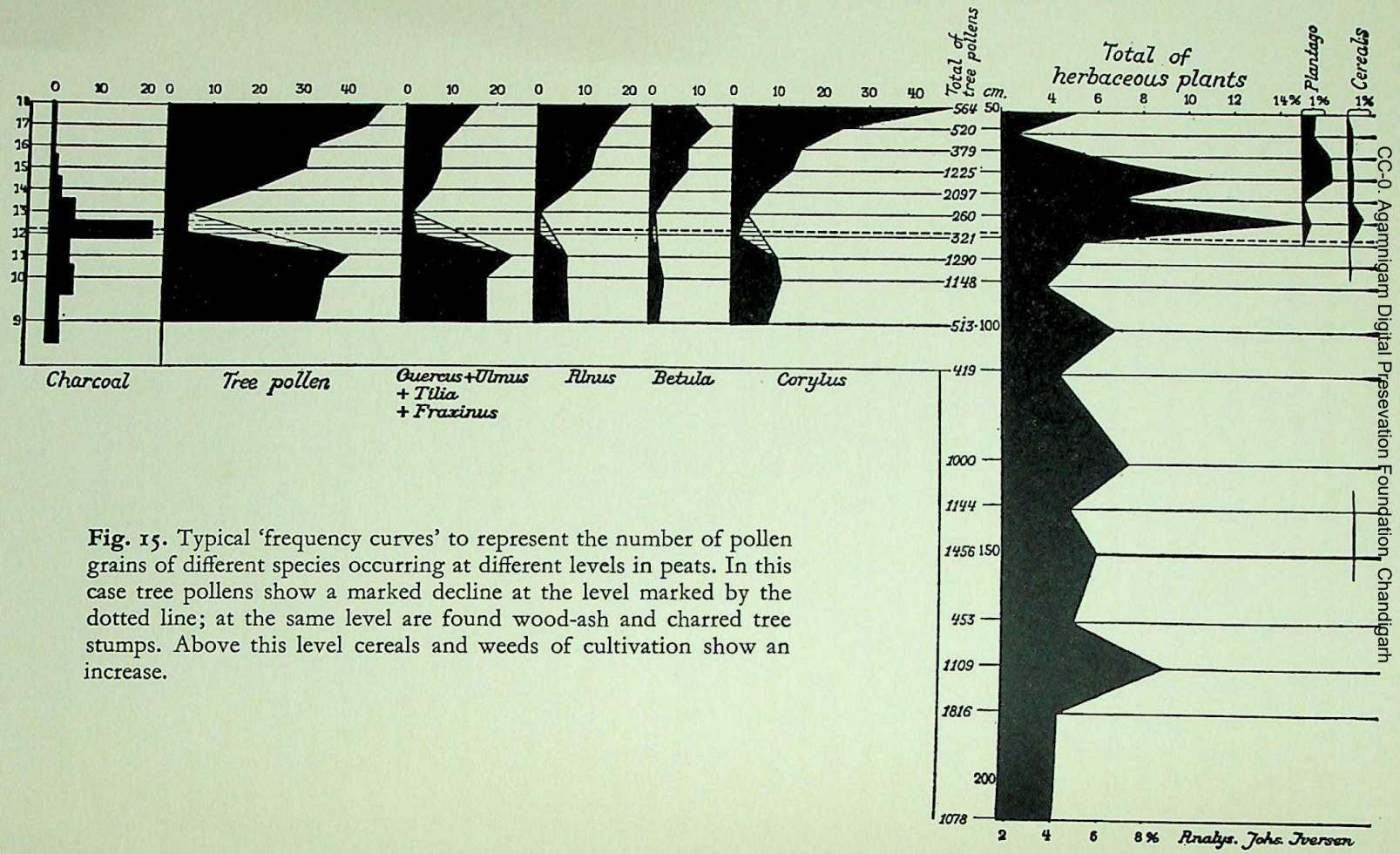


Fig. 15. Typical 'frequency curves' to represent the number of pollen grains of different species occurring at different levels in peats. In this case tree pollens show a marked decline at the level marked by the dotted line; at the same level are found wood-ash and charred tree stumps. Above this level cereals and weeds of cultivation show an increase.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

Almost as resistant to destruction as earthenware are the sinter produced by heating wood-ash and sand, which produces a true glaze, and glass which, like clinker, is a product of the heating of silica with salts and other bases. The fusion of masses of stone in the so-called 'vitrified forts' of Scotland was shown by Childe to be the result of the burning of timbers used in the construction of the walls.[1]

Exactly similar to potting is the making of fired bricks for building. As far as Britain is concerned the art of brick-making seems to have been lost with the departure of the Romans, not to come back (from Flanders) until about the middle of the fourteenth century, but throughout the principal building material was wood and many buildings of timber and wattle survive today.

It was comparatively easy for a destructive fire to start, either intentionally or accidentally, in a town built largely of wood. The resulting ashes would not be entirely cleared away but would be scattered and levelled ready for the erection of new houses. Ash-layers are therefore not uncommon in the accumulated debris of old towns: those associated with Boudicca's uprising and the Great Fire of 1666 are sometimes recognizable in excavations in London.

From earliest times thatching in a variety of materials, all inflammable, has been used for roofing, and so great was the fire risk that in London, following a great conflagration in 1213, roofs of reeds, rushes, and straw were forbidden; boards and shingles, only slightly less inflammable, replaced them.

It must be remembered that only candles and open flame lamps were available for lighting and that, without glass in their windows, in cold weather people were tempted to draw up their straw mattresses near to the open fire. Reeds on the floor served in place of carpets. It was inevitable that houses should frequently be destroyed.

Something will be said below about different building materials but it may be added here that an early improvement to the wattle frames, which were inserted into wooden frames, was the application of 'daub'—a coating of mud and straw. When fire broke out this daub was often heated to a temperature sufficient to bake it so that it became almost like pottery.

At Thundersbarrow Hill in Sussex fire preserved the clay lining to a flue, whilst in many places the former existence of wattles now destroyed may be inferred from impressions upon fragments of burned 'daub'.

The manner in which a burning house collapses is controlled by the progress of the fire: destruction of the tie-beams of a gabled roof

[1] V. G. Childe, 'The Experimental Production of the Phenomena Distinctive of Vitrified Forts', *Proceedings of the Society of Antiquaries of Scotland*, LXXII, p. 23, 1937–38.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

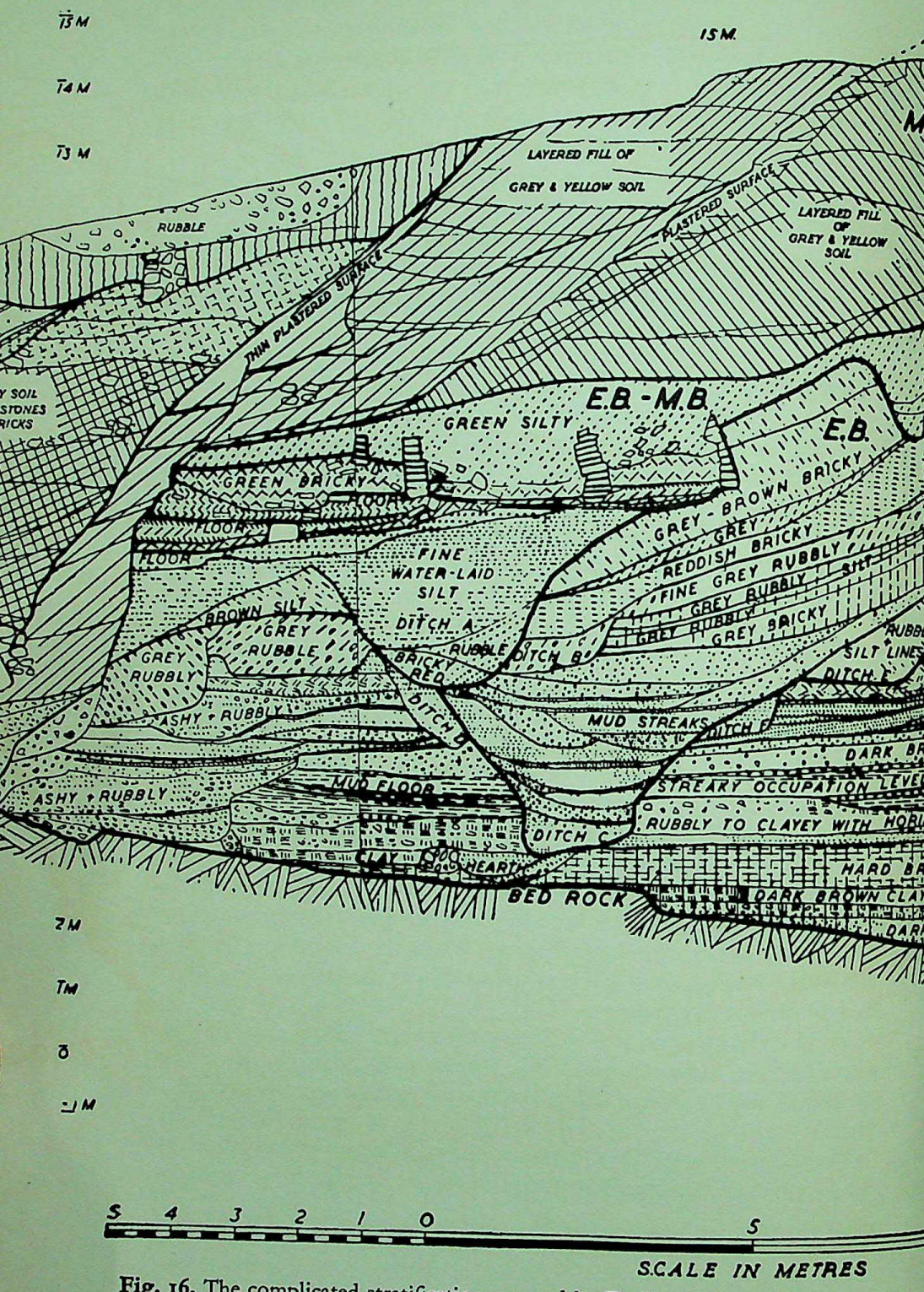


Fig. 16. The complicated stratification exposed by Dr K. M. Kenyon in her excavations through the accumulations resulting from successive occupations of Jericho, Jordan (see page 111).

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

releases thrusts which tend to force the tops of walls away from the centre of the building. On the other hand the collapse of the floor beams may tend to pull down superimposed walling towards the middle of the building. The introduction of steel girders into floors has meant an increase in the number of walls which fall outwards in a fire since expansion of the heated metal forces walls apart—wooden beams shrink with heat.

In connection with deposits resulting from man-made fires some notes made by Col. D. H. Gordon,[1] who reported on the planned destruction of a village in Waziristan, are of interest: 'The interior of a Wazi house', he wrote, 'where fires have burned for many years on an open hearth with no chimney and very little ventilation, presents a floor thickly coated with fine grey dust hopping with fleas and a brushwood ceiling kippered black by smoke.'

His concern however, was with huts and houses built of mud with little or no timber framing; of these he says: 'A house with mud and rubble walls and a flat mud covered roof has to be prepared for burning or it will not burn at all: the two essentials being extra fuel and a good draught. These houses will not burn by the simple application of a torch to such woodwork as forms part of their fabric: elaborate preparation must be made if they are to be even uninhabitable.'

The extent to which damage can be caused to constructions of different materials must always be borne in mind when dealing with deposits of burned matter, for only then will it be possible to attempt a reconstruction of events. A burned wall and thick ash layer within the mound at Jericho, for instance, will require interpretation in practical terms.

A further paragraph from Col. Gordon's paper may be appropriate:

'Wooden, reed or daub and wattle houses having thatched roofs could be fired without difficulty by raiders in a matter of moments, but houses with flat mud roofs, as are deemed to have existed throughout much of the Middle East, could not have been fired in the scramble of a raid and if no extra fuel were available they could not have been fired at all. There are two possibilities, either the tentative reconstructions of houses with flat mud roofs that are often made are in many cases incorrect or equally in many cases the so-called destruction level is nothing of the kind.'

Man as an animal is unique not only in burying—or cremating—his dead, but in normally making no effort to hide his home: unlike those animals which bury their droppings or those birds which carry egg-shells away from their nest, in primitive conditions he strews his

[1] D. H. Gordon, 'Fire and the Sword: the Technique of Destruction', *Antiquity*, XXVII, p. 149, 1953.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

rubbish around his habitation. Further he is unique in making imperishable substances such as glass and brick.

From his earliest hunter-fisher days, man has been a collector first of food and then of material for his comfort. Even where no other evidences of his habitation have been found, therefore, sometimes his rubbish heaps have been discovered. So great were the accumulations of sea-shells and other refuse found at Ertebølle in Denmark that they were called 'kitchen middens' and so great was the thickness that a miniature stratigraphy could be worked out.

At the site of the Late Bronze Age villa at Skara Brae in the Orkney Islands retaining walls had been built to hold back from the houses vast accumulations of kitchen refuse. The stench of decay and insanitary squalor seems in no way to disturb primitive communities. It is not difficult to find examples throughout the world of people who bury their dead beneath the floors of their houses. The classical writer Strabo was probably only slightly incorrect when he wrote of the Dardanians that they were 'so utterly wild that they dig caves beneath their dung-hills and live there'.

At Gua Cha in Kelantan, Sieveking found human remains surrounded by those of pigs but was able to explain his discoveries in this way:[1] 'The Neolithic burials, in general, seem to have been placed immediately below the level of the cave floor inhabited at the time and thus occur at all levels, the earliest being cut into the (Mesolithic) deposits beneath.'

The archaeologist's main source of information concerning the past comes from man's habit of collecting material things for his comfort and adornment. Largely he is concerned with structures set up to provide protection from the elements, either for man himself, his gods, or his food stores.

It was in 1773 that Boswell and Johnson undertook their famous tour of Scotland and the Hebrides. By the side of Loch Ness a few miles from Inverness they stopped to examine 'a little hut', and of it Boswell wrote: 'It was a wretched little hovel of earth only, I think and for a window had only a small hole, which was stopped with a piece of turf, that was taken out occasionally to let in light. In the middle of the room or space which we entered, was a fire of peat, the smoke going out at a hole in the roof . . . There was at one end under the same roof, but divided by a kind of partition made of wattles, a pen or fold in which we saw a good many kids . . . I went into the place where the bed was. There was a little partition of wicker, rather more neatly done than that for the fold, and close by the wall was a kind of bedstead of wood with heath upon it by way of

[1] G. de G. Sieveking, *The Illustrated London News*, 5 March 1955.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

bed . . .' There were five children and the parents were allowed to keep sixty goats in exchange for taking care of the landlord's woods. Boswell was told 'that they lived all the spring without meal, upon milk and curds and whey alone. What they get for their goats, kids and fowls, maintains them during the rest of the year.'

The following day Boswell and Johnson lodged in a house which 'was built of thick turfs, and thatched with thinner turfs and heath'. Where they sat, 'the side-walls were wainscotted', as Dr Johnson said, 'with wicker, very neatly plaited'. Their 'landlord had made the whole with his own hands'.

These rather lengthy extracts[1] are included first since they provide an account of a way of life which continued in the remoter parts of Britain for many years after Dr Johnson's tour and which cannot have changed greatly since the Neolithic period, and secondly in order that it may be noted that none of the materials used for these buildings could be expected to leave any trace other than a slight tumbled mound.

Col. Gordon[2] reminds us that in monsoon areas more houses collapse from the effects of rain than are ever destroyed by fire: so they probably did in the Hebrides.

In southern Britain the homes of the poorer classes away from towns must have been very similar to those in the north, though with a greater use of timber. Those who could afford them had houses with timber frames and walls of wattle and daub. Even less would remain of a deserted (but not burned) timber house than of one made of turves in spite of a constant need to repair the mud plastering on the wattle frames. Although by Shakespeare's time many timber-framed houses had stone or brick footings to the walls, his audience well understood Hamlet[3] when he said:

> 'Imperious Caesar, dead and turn'd to clay,
> Might stop a hole to keep the wind away:
> O! that that earth, which kept the world in awe,
> Should patch a wall to expel the winter's flaw.'

Such conditions may well explain the fact that few traces of Saxon villages have ever been discovered even where large and comparatively rich cemeteries are known. From an absence even of potsherds in such circumstances one may be compelled to assume an extensive use of perishable leather and wooden vessels.

Human settlements can be divided into four main classes, open temporary encampments, farmsteads, villages, and long-lasting cities

[1] James Boswell, *The Journal of the Tour of the Hebrides*, 30th and 31st August.
[2] D. H. Gordon, 'Fire and the Sword: the Technique of Destruction', *Antiquity*, XXVII, p. 149, 1953.
[3] *Hamlet*, V. 1.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

or towns—though between the categories there can be no clear dividing lines.

The lessons of man-made stratification can best be learned at a town which has been occupied over a long period and where the debris of successive generations has been allowed to accumulate layer upon layer over a fairly extensive area, but it must be remembered that, by very reason of the usually haphazard manner of their formation, human accumulations cannot be expected to lie in layers of equal thickness, or in even level spreads. The basic principles remain the same whether one is concerned with, say, the Roman and mediaeval city of London, the 'tell'[1] at Jericho, or a patch of ground four feet square. As an example of the last, one thinks of Egolzwil in Switzerland[2] where hearths had to be continually re-made as accumulations of dropped and discarded matter formed an ever-increasing 'habitation layer' both inside and outside the houses. The builders of what is called a 'Moorhaus', whose wooden floor was perfectly preserved, knew that the weight of the hearth would bring about a sinking of the floor into soft ground beneath. The hearth was therefore made in an open space in the floor and constructed on the bare ground below. In spite of this precaution the floor had to be renewed several times, and the hearth as well, so that the various layers of the hearth eventually attained a thickness of one metre.

The frequency with which the hearth was rebuilt would be controlled entirely by the whim of the users and no rate of increase in thickness can be calculated. A calculation of this sort was attempted by Braidwood[3] when, in considering strata in Jericho, he wrote: 'From information we could gather in a variety of villages in the piedmont of Iraqi Kurdistan, the average life expectancy of the *touf* or *libu* house of an ordinary *fellah* is about fifteen years. The debris product in mud is about two feet in height. At this rate, 350 years could easily accumulate 45 feet.' Dr Kathleen Kenyon, the excavator of Jericho, replied however[4] '. . . as to Professor Braidwood's suggestion that any sort of yardstick of a rate of accumulation of deposit on the tell of two feet every fifteen years can be employed—it just doesn't figure. The history of rise, collapse, denudation and embankment is far too complex.' The calculation of the period of time which would be required for natural agencies to form a 'soil' of a given thickness over a deserted and undisturbed tell (as was attempted at Jericho) can be regarded with rather more confidence.

[1] The word 'tell' is said by some to be derived from the Babylonian 'tillo', a ruin-heap.
[2] E. Vogt, 'Swiss pile-dwellings', *Antiquity*, XXXI, pp. 68 f, 1957.
[3] Robert J. Braidwood, 'Jericho and its setting in Near Eastern history', *Antiquity*, XXXI, p. 75, 1957.
[4] Reply to Professor Braidwood, same issue of *Antiquity*, p. 82.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

The tendency for a farm-house (or for that matter a hamlet, village, or town) to occupy exactly the same site as its predecessor is very largely a matter of economics. Apart from the fact that the natural advantages—drainage, water-supply, etc.—will probably remain the same as when first selected, much of the work on the site represents a capital investment; it is obviously most economical of effort and material to re-use and if necessary modify an existing castle wall or hill-fort rampart than to start on an entirely new one, but the same basic considerations apply even to the erection of a simple hut. Before the advent of the mechanical saw many hours or days were required for the production of a wooden beam and when transport was a matter of difficulty it was simplest to re-use old beams and planks on the same spot. It was the same with building-stone. The collection of building-stone involves much labour: there are indeed historical records of the demolition of the cathedral at Old Sarum and the use of the materials in the building of a new one in the early thirteenth century at Salisbury. But it was not until the introduction of the horse-drawn cart that any large-scale robbing of materials from one building for the construction of another at any distance could even be considered.

Destruction of an earlier building was often so complete as to leave in the ground, where even the foundations had been removed, only 'robber trenches' which may show in excavations as rubble-filled ditches cut into earlier deposits or natural soil.

At Lindholm, in Denmark, Viking settlers used to outline graves with stones set into the ground in curved rows to resemble the shapes of ships, but in places only 'ghosts' of these ship graves show up; for when the stones were stolen, no doubt to surround a later burial, sand blew into the sockets, which now survive as white patches in darker soil.

The light sandy soil of these sockets in fact represents the remnants of a considerable bank which blanketed the whole site; upon the surface grew up an eleventh-century settlement. Later on the site was abandoned and not re-occupied and most of the sand was blown away again, so that, of the settlement, the only signs today are the holes in which posts were erected and the slots into which wooden walling was inserted.[1] The source of the sandy earth is mentioned on page 116.

The tell at Jericho provides but one instance of the results of continued human occupation of a site. Late Stone Age men were the first to leave evidence, in the shape of Natufian stone implements, of their having camped by the spring of fresh water (Elijah's Well) which

[1] T. Ramskou, 'Uncovering the Largest Viking Cemetery in Denmark', *The Illustrated London News*, 13 August 1955.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

continues to supply a small oasis in the rain-shadow desert of the Jordanian rift valley. Later peoples, those of a Pre-pottery Neolithic period, settled upon the same site and built around their hamlet a defensive wall of large stones. There followed them makers of pottery and people who had learned the process of making sun-dried bricks; with these they constructed huts and houses. Each generation left on the spot materials which it had brought there for its comfort.

Whatever steps were taken to level, dig into, or move what had accumulated, to no one was it necessary or economic completely to remove it when a building collapsed or had served its purpose. It was simplest to rake what remained of the not imperishable mud bricks into a more or less level platform, to make and bring to the site new bricks and to build on top of the old. A mud or plaster floor would not be removed but would be repaired by spreading a few inches of new flooring above it. (At a Pre-pottery Neolithic site at Khirokitia in Cyprus one house had no fewer than seventeen superimposed floors; at Jericho there were twenty-one floors in one place and in another seventeen successive mud-brick walls.)

So, over some six thousand years, there grew up a tell-mound covering six to eight acres; within it are buried the remains of many successive city walls. Eventually the city, as it had become, was destroyed and abandoned; according to the Biblical record: '. . . they utterly destroyed all that was in the city . . . and they burned the city with fire . . . and Joshua adjured them at that time, saying, Cursed be the man before the Lord, that riseth up and buildeth this city Jericho . . .'[1]

The site was never fully re-occupied, no more building materials were accumulated or refuse thrown out of doorways; the mound no longer grew and no one repaired the ravages of the elements, which have removed all trace of the walls round which Joshua's men marched and of the people whose city he destroyed in the latter part of the second millennium B.C.

A great trench cut by Dr Kenyon into the tell shows layer upon layer of occupation debris. It was for her to work out the story of the successive occupations of the site and to determine by which occupants each wall and hut was made.[2] The complexity of her task and the difficulties of relating pits and foundation trenches to the levels from which they were cut are clearly indicated by her drawing, part of which is reproduced (Figure 16).

The cutting into the tell at Jericho illustrated in itself an important aspect of stratification, namely that of compaction. Throughout the working, no shuttering was needed to hold the deep trench sides from

[1] Joshua vi. 21–6.
[2] See K. M. Kenyon, *Digging Up Jericho*, Benn, 1957.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

falling in, the weight of the superimposed strata having so compressed those below as to make them solid and stable. Earth-pressure had flattened and distorted most of the skeletons and the plastered skulls found buried some 8 metres from the present surface of the mound.

It may be as well to note at this point that no disturbed soil ever falls back as compactly as when nature originally sorted it—often under water. Earth dug from a grave or ditch, when thrown back, will always be found to be more than will fill the hole from which it came—but, partly under its own weight, partly as a result of the washing in of rain, and partly as a result of trampling, it will slowly settle. A house built on or partly on what is called 'made ground' will tend to sink unevenly and its walls will crack as its weight helps the earth beneath to compact. Further, loosened earth, even upon a level surface, tends to spread laterally so that it may cover at one level and under one uniform stratum relics of different periods. The archaeologist should therefore understand exactly the nature of any deposit which he regards as safely sealing artefacts below; indeed where such normal spreading has not taken place one is compelled to ask oneself the reason.

It would seem, for instance, that the reason for British Bronze Age barrow mounds retaining much of their original shape must be sought in the manner of their construction; in all probability loose soil was not just thrown upon the mound from a distance but must have been deposited, maybe in small basketfuls, by a succession of workmen each of whom trampled and so compacted what had previously been put into position. Such trampling and compaction would result in faces much steeper than would be formed in the event of the mound material's being allowed to adopt its normal 'angle of rest'.

Before we consider further the formation of strata in places of settled occupation two effects of natural denudation upon such sites must be mentioned.

First, any house or boundary wall built across the slope of a hillside acts as a barrier to normal downhill 'soil-creep'. 'Rain-wash' will pile up against the wall, layer by layer, and a miniature sequence of strata will be formed; eventually the wall may collapse under the weight of earth. This seems to have been the case at Lullingstone mentioned above (page 35).

Secondly, when man occupies certain kinds of site there is never really a permanent occupation surface. As an example one may take the case of the Neolithic people who lived at the foot of a sandstone cliff at High Rocks, Tunbridge Wells, Kent. Although overhanging rock protected the camp from the direct fall of rain, every shower produced trickles and rivulets down vertical fissures in the rock face,

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

so that there were always active fans of sand and soil spreading into the area of occupation. It is easy in such conditions to mistake for hearths and occupation 'floors' what are in fact mere spreads of hill-wash streaked with patches of immature soils and with twigs and humus washed from above. The working out of the stratigraphy of such a site and a sequence for pottery, etc. discovered there must be extremely difficult.

Mention has been made above of stratification to be found in middens but much care is needed in interpretation for the very nature of a rubbish tip involves the haphazard dumping of separate bucketfuls of material, each one forming a small loose cone; further, individual fragments may be thrown upon the heap. Thus, whereas in general terms the oldest matter will be at the bottom, in detail no order of deposition is likely to be worked out.

There will be uneven settling and much burrowing by scavengers, and there will also be lateral slipping. Such slipping can often be seen when the material filling ditches is exposed in sections. In a cutting across the Neolithic ditch at Windmill Hill the skulls of cattle, which had been thrown into the hollow, appeared to have been neatly deposited one above the other, whereas in fact each in its turn had probably rolled to the centre of the slowly filling ditch and then been covered by later debris.

One might expect a disused well, clogged with the slow aggregation of natural and artificial fillings, to present an even sequence of level strata from bottom to top, but in fact wells are notoriously disappointing to the excavator; partly because of just that overlapping of cones described above and partly because they are often cleaned out while in use and then filled in completely at one time.

From wells one is led to think of the fillings of pits. During the Early Iron Age in Britain it appears to have been the practice to store grain and other perishables in pits dug into the ground. When they became fouled or infested new pits were dug and the old ones filled in; any available refuse or rubble might be used but there is at least a probability that the refuse would be more or less of one date and roughly contemporary with the in-filling. It is important for the archaeologist therefore to take careful note of the closely associated contents of each pit of this kind.

In mediaeval towns rubbish pits were cleared out from time to time and again one can expect the contents of any pit remaining uncleared to be roughly contemporary. Such clearing and tidying of an occupied area must not be regarded as typical only of comparatively civilized communities, for there is evidence that floors were swept in very early times—to the disappointment of archaeologists most of

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

whose information comes from what has been carelessly dropped or abandoned as useless. At Trevisker Round, St Eval, Cornwall, the floor of a Bronze Age house had been so often swept as to produce a saucer-shaped hollow. What were at first fairly deep holes dug into the soft shaley floor to receive the upright posts, which formed the frame of the building, had been reduced in some places to mere shallow depressions, whilst in others a hollow cylinder of shale rising above floor-level showed where sweeping had almost but not quite extended up to a wooden column.

Lethbridge[1] too, writing of the occupiers of the Scottish 'wheel-houses', says: '. . . they were a cleanly people and swept out their houses. There is no trace of the deep deposit of ancient filth one sometimes finds in an old Eskimo winter house.'

A few notes on the mediaeval scene in Britain will assist an appreciation of the speed with which 'occupation layers' can accumulate; many of the following are taken from the work of G. T. Salusbury.[2]

In 1481 a road just outside the town of Canterbury was repaired by laying faggots of broom in the ruts and in 1428 willows from the roadside were used for a causeway outside Cambridge. Obviously materials were dependent upon supplies and transport facilities: '. . . stone, gravel and sand were the basic materials of the paviour's art, but fine earth and even vegetable matter were sometimes used. Constant patching rapidly raised the street levels and the hand-operated rammer was the only means of providing a surface.'

'The paviour', says Salusbury, 'always seems to have avoided the Roman practice of laying down a foundation or road bed of large stones . . . in streets where heavy traffic was expected . . . such thoroughness of preparation would have involved great delay and loss to traders.' To understand the last remark it must be recalled that traffic was concentrated at gateways through city walls and that streets were mostly too narrow to be repaired, as nowadays, one half at a time.

Pigs, geese, goats, and ducks fed in the highways and left their filth after turning over the butchers' and fishmongers' offal and the household refuse there. There was no one to remove stable manure and dead animals which could not be carried to the river were flung over the wall or onto waste spaces. Daily more food, clothing, building materials, tools, and furniture were brought into the towns; hardly anything left them.

With drains few or lacking, rain-water helped to spread the accumulation, and cut gulleys into it, for the provision of roofs to houses means an artificial concentration of rain-water; where it cannot find its way

[1] T. C. Lethbridge, *The Painted Men*, Andrew Melrose Ltd., 1954.
[1] G. T. Salusbury, *Street Life in Mediaeval England*, Pen-in-Hand, Oxford, 2nd ed. 1948.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

immediately into the ground it must seek some channel. Water from the roof-eaves would run into the roadway, cause puddles and gulleys, and soon necessitate another spread of gravel on the road, which while filling the holes would also bury some of the filth.

It is interesting to note that in London today the amount of soot and other solid matter from the city's air and pavements into the drainage system is of the order of one ton per square mile per day! Were it not for drainage—and regular clearance of the drains—a substantial mass would accumulate in the course of a very short time.

Desertion of a site may be occasioned by a variety of reasons—economic, military, climatic, etc. In England abandonment of many 'lost villages' has been attributed to the Black Death and other epidemics, but whatever may have been the cause one can hope to find at the sites of such settlements a sealing of natural deposits protecting intact and *in situ* artefacts and structures which might otherwise have been destroyed by subsequent dwellers on the spot. For this reason alone it is important that they should be recognized and investigated before the modern deep plough destroys them.

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

12

Interpretation

IT SHOULD BE the task of the archaeologist to interpret and understand not only man's activities and artefacts but also the nature of the natural strata on, in, and under which they are discovered.

The tracing of the source of the material of which a stratum is composed may lead to important conclusions regarding the sequence of events not only at a particular site but in the surrounding countryside. For example, of the settlement at Lindholm in Denmark, sited on a windy hill-top and later abandoned in favour of a more sheltered place, it was possible to write: 'The presence of this settlement, lying so near the cemetery, explains how the sand-dune came to cover the cemetery and where it came from. It must have come from the fields belonging to the settlement.'[1]

Entirely upon the configuration of the land-surface and upon past and continuing natural processes of erosion and deposition will depend the very survival or destruction of an ancient settlement. Only a study of the land-surface and of the strata themselves will permit a decision as to whether archaeological finds are in their original position—whether the discovery of a few sherds of Neolithic pottery in the silt filling an abandoned river course are likely to lead to the finding of further Neolithic remains at that level, or whether they indicate only that three thousand years later a Norman boy threw at some floating log the first convenient missiles which came to his hand.

As has been said above, in the chapter dealing with frost-weathering, an appreciation of natural processes assists in preventing the interpretation of natural phenomena as evidences of human activity; the recent argument as to the existence or otherwise of grown-over figures cut, like the white horses, into the turf could not have taken place had there been a better understanding of the gullying and shattering of the chalk surface below the turf.

Having read the foregoing chapters the beginner in archaeology will perhaps also fall less easily into the traps which have led some field workers in the past to interpret natural horizontal streaks of manganese and iron salts in their sections as evidences of man-made

[1] T. Ramskou, 'Uncovering the Largest Viking Cemetery in Denmark', *The Illustrated London News*, 13 August 1955.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

fires, or tree-root hollows as artificially excavated 'underground houses'.

The interpretation of strata and stratification however is something requiring special skill and much experience. It is perhaps comparatively simple to differentiate at sight between a man-made burial mound and a natural hillock, but even here there may be traps; those remnant patches of gravelly Pleistocene clay which sometimes lie on the surface of the chalk downs can occasionally be deceptive: they accumulate acid rain-water within themselves and slowly dissolve the alkaline chalk beneath them, so that they settle gradually into solution hollows. The detailed interpretation of the several strata comprising a burial mound and filling its quarry-ditch, however, requires skill and an ability to observe which can be learned only by long experience of actually excavating and sectioning earthworks under the tutelage of an experienced excavator who is familiar with the local rocks and soils. Only then will an archaeologist be able to suggest, from the now eroded, altered, and compacted remnants, what may have been the form and method of construction of the original artificial work.

Only after similar training will an excavator be able to learn from the stratigraphy of a long-occupied settlement something of the sequence of events which led to the present series of strata.

Indeed, whilst the basic principles of stratification are universal, each kind of site requires a different kind of experience; many years' experience in excavating Bronze Age barrows, whilst useful, will not necessarily equip an archaeologist to understand the stratification of deposits in a Roman or mediaeval town, or lead to an understanding of the problems involved in relating Palaeolithic implements to cave-earths, river gravels, and boulder-clays. The required approaches are very different. The excavator of a barrow a few feet across need be concerned with very little beyond the outer lip of the surrounding ditch. Apart from a few intrusive late burials inserted into the mound he will be concerned with a monument more or less of one date: his main interest will be in ascertaining how the barrow was built (and by whom) though he will have to satisfy himself as to which burials are primary and which secondary.

The excavator of a settlement site, on the other hand, will be concerned with much more extensive strata and one of his objects will be to trace such layers, disturbed as they may be, from one building to another. He may also expect to find successive layers, each with artefacts appropriate to the period, lying one above another. On the other hand, strata upon a settled site are not like the skins of an onion to be peeled off in strips of even thickness but are full of humps, hollows, and hiatuses.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

'Once on removing a very ancient boundary wall of stone (at Tell en-Nasbeh) . . .' Bade[1] '. . . found preserved, underneath, a long strip of Byzantine occupation level, which stood eighteen inches above adjacent areas that had been denuded of this level by a combination of tillage and weathering.'

As the excavator proceeds he will seek to show that, for instance, whereas the remains of two buildings are contemporary, the stratum which links them passes over or under other structures which will thereby be proved to be earlier or later in date. Incorrect excavation methods destroy the continuity (Figure 17). He will not expect the strata to lie always level or to be of equal thickness, yet he must trace them over the whole of the space he wishes to bridge. Unless he follows a layer of ashes from one area to another he cannot be certain that two ash-streaks in separated excavation trenches are the result of the same conflagration.

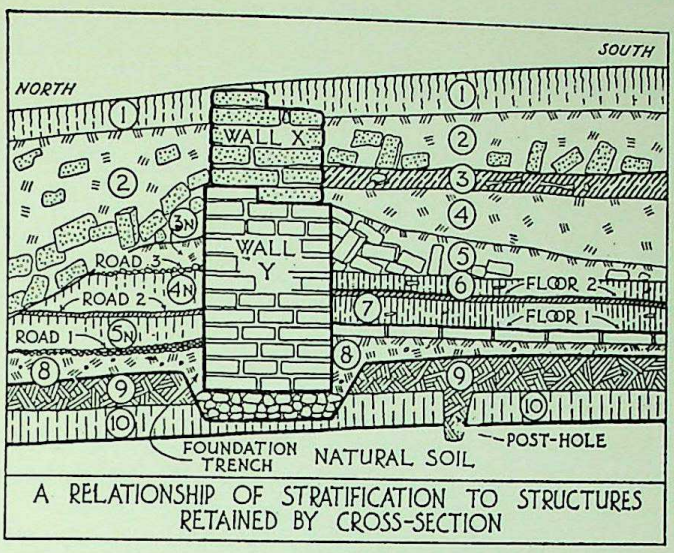
Failure to trace the entire length of a stratum between two exposures has sometimes led to misinterpretation: Figure 5 shows clearly how a misunderstanding of this kind may occur: 5a shows an interpretation based upon an incomplete exposure of a succession of deposits at Hoxne in Suffolk from which has come an important series of Palaeolithic implements; 5b shows how, after excavation and clearance of a quarry face, quite a different story could be told.

It is only fair to say that the student of the Old Stone Age faces difficulties which seldom present themselves to archaeologists concerned with later periods. The layers of boulder-clay, gravels, and sands for which he seeks an order and sequence may extend over many counties and even be of hundreds of feet in thickness. He must seek the records of well-borers, railway and other civil engineers, and quarrymen; he cannot hope to section such vast deposits and must rely largely upon the geologists to assist him in determining the age and nature of the strata between which lie his archaeological finds.

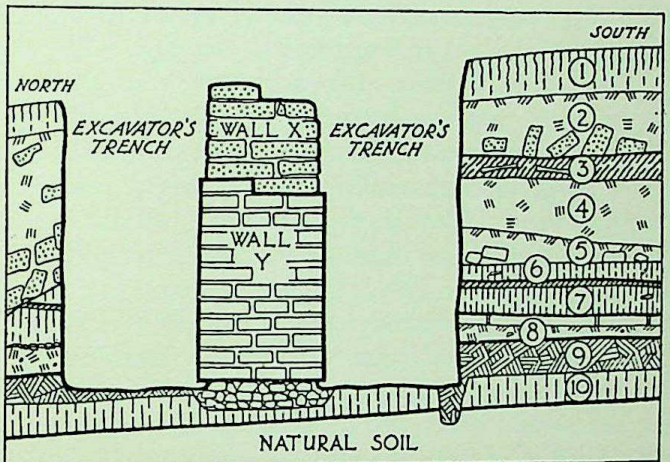
At the same time by his own observations he should be able to know whether his finds are coming from disturbed ground or from strata which are lying in the position in which they were first laid down. When, in 1859, Sir Joseph Prestwich and Sir John Evans accepted the discoveries of Boucher de Perthes in the valley of the River Somme, history was made not so much by their accepting the implements as made by man as by their recognition of the fact that they came directly from undisturbed gravels of great antiquity. Archaeological deduction thus followed geological (stratigraphical) observation, as indeed it always should, for otherwise there is some danger that argument may go 'in circles'.

[1] W. F. Bade, *A Manual of Excavation in the Near East*, University of California, 1934.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh



A RELATIONSHIP OF STRATIFICATION TO STRUCTURES RETAINED BY CROSS-SECTION



B. THE SAME RELATIONSHIP OBLITERATED BY CONTINUOUS TRENCHING

Fig. 17. 'Incorrect excavation methods destroy the continuity.'

If the archaeologist is seeking to establish a chronological sequence for his Palaeolithic implements and for the purpose relies upon geological evidence, the geologist cannot also seek to provide relative dates for his gravels by reference to the types of implements found in them!

The principle of dating strata merely from included artefacts cannot safely be applied unless firmly established types are concerned. In Britain the Neolithic polished flint axe would probably be the earliest

CC-0. Indian Institute of Advanced Study. Digitized by Sarayu Foundation Trust, Chandigarh

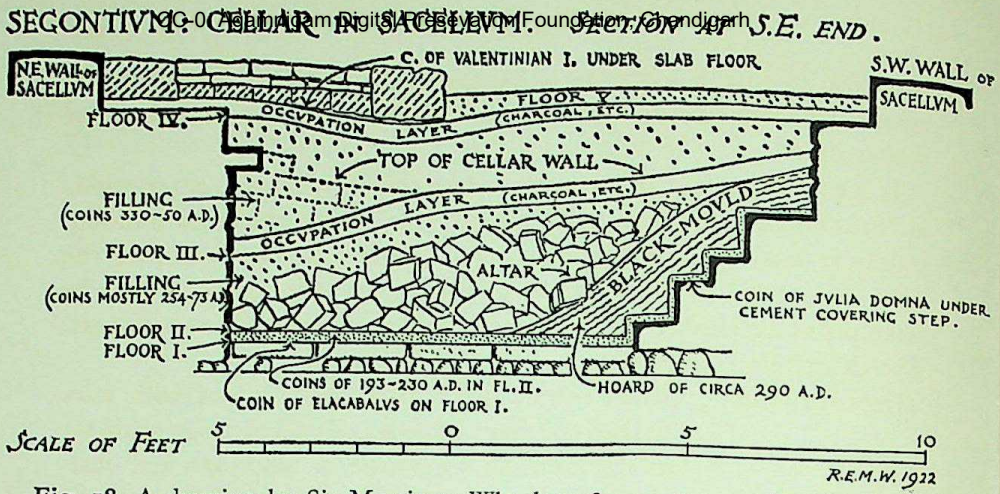


Fig. 18. A drawing by Sir Mortimer Wheeler of a section cut by him through layers filling a Roman cellar; a careful noting of the exact positions where coins were found assisted in the dating of various phases.

tool usable in this way, but no real certainty can be felt until datable coins are found in well-sealed levels (see Figure 18).

The intersection of different strata is another matter. If a Roman road can be shown to cut into a barrow, clearly that barrow ante-dates the road. Careful examination of a section through the material filling overlapping post-holes will usually show which hole was dug first, while it is even possible, from a close examination of the dragged edges, to say which of two lines engraved on a piece of metal was scored first.

In the latter part of the sixteenth century Ralph Agas wrote of land surveys: 'Without good and exact Surveighes, manie slippes, escapes, and evations wilbe committed of great momente and weight.' This statement holds good when the publication of archaeological strata is in question. Surveys of surfaces must be accompanied by scale drawings of sections through the strata so that there is a three-dimensional record.

For easy comprehension strata should be represented by standardized conventional representations and if layers are given numbers they should always be numbered in the order of their deposition—No. 1 at the bottom, both in drawings and in time-scale diagrams. The historian's method of writing his earliest dates at the head of his page should be avoided.

The object of any archaeological excavation or other investigation should be to provide answers to questions, and the intention behind the recording of stratification should be to provide information on a sequence of events. There is thus little or no point in making a drawn record of strata if the record fails to provide (a) an intelligent inter-

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

pretation of such a sequence of events or (b) (when an interpretation cannot be made on the spot) proper information for interpretation at a later time.

It is almost useless, in a report, to label layers with such descriptions as 'greyish rubbley' or 'yellow sandy'; these names have no meaning unless at least some reference is made in the text accompanying the drawings to the detailed nature of the strata. More useful would be attempts at explaining the presence of the layers and their constituents. The descriptions might be improved as follows:—

'Greyish rubbley'. Much rubble fallen from walls mixed with rain-washed soil from hillsides. A greyish tinge probably results from an admixture of wood-ash and charcoal. Sample taken for close examination.

'Yellow sandy'. Natural ferruginous water-bedded sand. Brought to site either by former tributary stream (course not ascertained) or as a result of flooding of main river.

Such descriptions at least attempt to add something to the story of the excavated area.

The archaeologist must seek to solve his problems by his own special methods; access to the microscopes and laboratories of experts in other fields is useful but is not a substitute for careful observation on the spot. Too much faith can be placed in scientific investigations which the archaeologist cannot pretend properly to understand and Gill has given a useful warning about the dating of natural deposits by radioactive carbon. He writes:[1] 'The writer's experience is that C_{14} cannot replace the patient field work of geologist and archaeologist, but is a check for it and an added refinement to it. For example a C_{14} date of about 3000 years was received for charcoal from the Keilor Terrace of Braybrook, near Melbourne. This result did not fit the geological evidence, so check assays were made, indicating a date of about 8500 years for the upper part of the terrace. If the first date had been obtained without field work, it would no doubt have been accepted, and the dating of the processes of terrace formation, erosion and soil development, the dating of Keilor Man, and so on, would have been in error by a factor of three.

'Infinite pains need to be taken in the collection of field samples and in the assessment of their significance. Contamination can easily occur; field problems are numerous. For example, when a sample of peat is collected one needs to consider not only its geological provenance but also its botanical composition, and its history subsequent

[1] E. D. Gill, 'Radiocarbon Dates for Australian Archaeological and Geological Samples', *Australian Journal of Science*, Vol. 18, No. 2, October 1955.

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

to formation. A sample of moss peat may consist only of material belonging to a given time, but peat from a herbaceous flora may consist in part of the peat of the given times and in part of the decomposed roots of plants that lived hundreds of years later. Even in the instance of moss peat, climatic change may have caused a drying of the swamp, so that a forest covered the area and tree roots of centuries or millennia may have penetrated to the horizon concerned and decomposed there. As C_{14} dating becomes more precise, such considerations become the more significant. One needs to know what one is dating. Indeed, the writer regards this as *the fundamental point in using C_{14} dates—to determine precisely what has been dated.*'

For the stratigrapher the lesson is that he should determine precisely the nature of his strata!

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

INDEX

Black Rock, 45, 46, 64, Fig. 3
Borough Green, 45
Brean Down, 45

Cae Gwyn, 49
Caldey Island, 40
Callernish, 94
Cambridge, 114
Canterbury, 114
Clacton, 62
Cromer, 62
Culbin, 29

Darenth Wood, 35
Domslandsmoor, 95
Dungeness, 59

Egolzwil, 109
Ehringsdorf, 41
Elie, Plate VIII
Ertebølle, 107

Farnham, 76, 94, Fig. 9 (a & b)
Fayum, 30, 31, 56
Ferrassie, La, 52
Font Echevade, 40

Glastonbury, 72
Grotte du Prince, 63
Gua Cha, 107

Herculaneum, 24
High Rocks, 112
'Himalay mountains', 13
Hong Kong, 35, Plate V
Hoxne, 14, 49, 118, Fig. 5 (a & b)

Jarlshof, 30
Jericho, 20, 35, 106, 109, 110, 111, Fig. 16

Keilor, 121
Kent's Cavern, 14, 52, 79
Kharga, 31, 41, 42
Khirokitia, 111

Lepcis Magna, 30
Lindholm, 110, 116
London, 97, 103, 109, 115
Lullingstone, 35, 112
Lynmouth, 34

Mohendjo-daro, 66

Newhaven, 59

Old Sarum, 110
Oldbury, 21
Olduvai, 55
Ostrave-Petrokovice, 15

Peacock's Farm, 29, 91, Fig. 12
Pompeii, 24

Ras el Nakb, Plate IV
Richborough, 73
Rusinga Island, 75, 76

St Catherine's Monastery, Plate I
Salisbury, 110
Seaford, 59
Segontium, Fig. 18
Selsey Bill, 61
Skara Brae, 30, 107
Slindon, 61

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

Stane Street, 21
Starunia, 75
Stonehenge, 21, 37, 82
Swanscombe, 45, 62, 67, 68, 77, Fig. 6

Tell-el-Nasbeh, 118
Thatcham, 93
Thornborough Rings, 39
Thundersbarrow Hill, 103
Tollund, 95
Trevisker Round, 114

Udal, 30

Verulamium, 81
Victoria Cave, 79

Wallertheim, 39
Windmill Hill, 37, 113
Woodcuts, 20

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

CC-0. Agamnigam Digital Presevation Foundation, Chandigarh

Books on Archaeology and Anthropology

FROM PHOENIX HOUSE

A Companion Volume to *Stratification for the Archaeologist*

SOILS FOR THE ARCHAEOLOGIST *Dr I. W. Cornwall*

'. . . has succeeded in his primary aim of forging a useful bridge between the field archaeologist and the "soil expert". Both should most emphatically read this book.'
R. M. S. PERRIN in *Soils and Fertilizers.*

Illustrated with line drawings and diagrams. 50*s net*

The ABC of information about Animal and Human Structure

BONES FOR THE ARCHAEOLOGIST *Dr I. W. Cornwall*

'Dr Cornwall has provided for the first time in a compact and readable form the kind of information about animal and human bones which archaeologists need.' *Man.*

Illustrated in line by M. MAITLAND HOWARD. 50*s net*

Standard Textbooks on the Subject

ARCHAEOLOGY IN THE FIELD *O. G. S. Crawford*

An exhaustive book on standard equipment for all practitioners. Packed with facts and ideas.

Illustrated with plates, etc. 4th edition. 45*s net*

AN ARCHAEOLOGICAL GUIDE AND GLOSSARY *James Stewart*

'The apt illustrations and diagrams and the clear explanatory text make this an excellent "field-book" for the amateur archaeologist!' *British Book News.*

2nd edition. 25*s net*

BEGINNING IN ARCHAEOLOGY *Kathleen Kenyon*

A veritable encyclopaedia in miniature for the student, including a section on careers.

Illustrated with plates and diagrams. 16*s net*

Picture of a Prehistoric Britain

AN ARCHAEOLOGY OF SOUTH-EAST ENGLAND *Gordon J. Copley*

Britain, from paleolithic down to late Saxon times, pieced together from a region particularly rich in discovery and finds.

Illustrated with plates, maps, diagrams and Gazetteer of 1,800 place names. 50*s net*

A big book about the little-known Single Grave People of the second millenium B.C.

THE BRONZE AGE ROUND BARROW IN BRITAIN *Paul Ashbee*

Round barrows, which still lie in their thousands on the downs and moorlands of Britain, cover the graves of a secret people. Deductions are made from this rich island heritage and placed in relationship to the wider European period scene.

Illustrated with plates and figures in the text. 50*s net*

The Carnegie Medal winner on the Evolutionary Story

THE MAKING OF MAN *Dr I. W. Cornwall*, with drawings and reconstructions by *M. Maitland Howard*

Writer and illustrator of *Bones for the Archaeologist* here reviews the latest advances in the discovery of man: they go beyond the missing links in piecing together man's ancestral tree.

With line drawings in two colours throughout. 10*s* 6*d net*

All these books are published by Phoenix House Ltd, 10–13 Bedford Street, London, W.C.2, along with many others: send for four-page descriptive prospectus, or ask your bookseller for a copy.